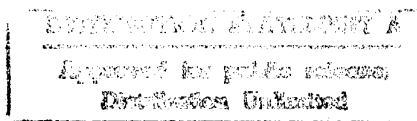


# Final Data and Analysis Report on: High-Resolution in Plume Concentration Fluctuations Measurements using Lidar Remote Sensing Technique

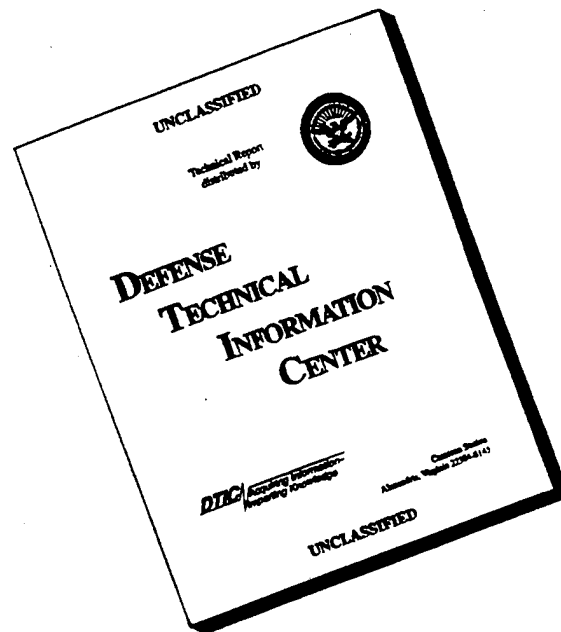
Torben Mikkelsen, Hans E. Jørgensen, Søren Thykier-Nielsen,  
Søren W. Lund and Josep M. Santabarbara



19960229 082

DTIC QUALITY INSPECTED 1

# DISCLAIMER NOTICE



**THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.**

**Final Data and Analysis Report on:  
High-Resolution in Plume  
Concentration Fluctuations  
Measurements using Lidar  
Remote Sensing Technique**

Risø-R-852(EN)

**Torben Mikkelsen, Hans E. Jørgensen, Søren Thykier-Nielsen,  
Søren W. Lund and Josep M. Santabarbara**

**Risø National Laboratory, Roskilde, Denmark  
November 1995**

**Abstract** The multi-nation, high-resolution field study of Meteorology and Diffusion over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexafluoride (SF<sub>6</sub>), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and SF<sub>6</sub> were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simulations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and depth of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

ISBN 87-550-2124-7  
ISSN 0106-2840

Grafisk Service, Risø, 1995

# Contents

## **1 Introduction 5**

- 1.1 Summary 5
- 1.2 Objectives 6
- 1.3 Background 7
- 1.4 Reporting and Availability of Results 7
- 1.5 Acknowledgements 8

## **2 Technical Description 8**

- 2.1 Mean and Turbulence Measurements from two Micro-Meteorological Masts 8
- 2.2 High-Resolution Time-Series and Spectral Analysis 9

## **3 LIDAR-Measurements of Surface-Released Smoke Plumes 10**

## **4 Modelling 11**

- 4.1 Mean-Flow Modelling: Real-Time Diffusion Model Simulations 11
- 4.2 Combined Mean-Wind and Dispersion Models for Real-Time Plume Dispersion Assessment over Undulating Terrain 12

## **References 13**

## **Appendix II 16**

### **Appendix II.1 24**

### **Appendix II.2 37**

### **Appendix III.1 43**

## **Appendix IV 77**

## **Appendix V 85**

RISØ  
PARTICIPATION IN:

THE  
MADONA  
EXPERIMENTS:

(Meteorology and Diffusion Over Non-uniform Areas)

UK PORTON DOWN

7-25 SEP. 1992.

Final Data and Analysis Report on:

HIGH-RESOLUTION IN-PLUME CONCENTRATION FLUCTUATIONS  
MEASUREMENTS USING LIDAR REMOTE SENSING TECHNIQUE

by

Principal Investigator:  
Torben Mikkelsen, Ph.D

Associate Investigators:  
Hans E. Jørgensen , Søren Thykier-Nielsen, Søren W. Lund and Josep Moreno  
Santabarbara

Department of Meteorology and Wind Energy  
Risø National Laboratory, DK-4000 Roskilde, Denmark

Sponsor:  
U.S. Army, Environmental Sciences Branch, "R&D 6858-EN-09"  
Contract No. DAJA45-92-M-0344

# 1 Introduction

## 1.1 Summary

The multi-nation, high-resolution field study of Meteorology And Diffusion Over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexafluoride ( $\text{SF}_6$ ), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and  $\text{SF}_6$  were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simulations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and depth of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

1. US Army Research Laboratory, White Sands Missile Range, NM, USA;
2. German Military Geophysical Office, Mont Royal, D-56841 Traben-Trarbach, Germany;
3. US Army Dugway Proving Ground, Dugway, Utah;
4. Chemical and Biological Defence Establishment, Porton Down, Salisbury, Wiltshire, United Kingdom;
5. TNO Prins Maurits Laboratory, Rijswijk, The Netherlands;
6. National Defence Research Establishment, Department of NBC Defence, S-901 82 Umeaa, Sweden;
7. Department of Meteorology and Wind Energy, Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark;
8. Meteorological Office, Larkhill, Wiltshire, United Kingdom;
9. German Aerospace Research Establishment, Oberpfaffenhofen, Germany.

The Department of Meteorology and Wind Energy at the Risø National Laboratory in Denmark participated and supported:

# *MADONA:*

## *Meteorological And Diffusion Over Non-uniform Area*

Full-Scale Diffusion Trials Conducted at

Porton Down, Salisbury

CBDE-UK; Sep. 7 - 25 1992.

The Risø National Laboratory, Department of Meteorology and Wind Energy, contributed with the following activities:

- 1) Continuous smoke dissemination from ground level sources.
- 2) High-resolution profile-measurements of instantaneous plume dispersion and concentration fluctuations by use of a mini-LIDAR system. (Remote sensing)
- 3) Micro-meteorological measurements of wind and temperature quantities from two 7 meter tall met-towers equipped with 20 Hz sonic anemometers for characterization of the mean and turbulent state of the boundary layer.
- 4) Mean wind and diffusion modelling using our real-time diagnostic models LINCOM/RIMPUFF.

### **1.2 Objectives**

The scientific objective for our participation in MADONA was to investigate fundamental questions regarding the statistical properties of the instantaneous concentration fluctuations in smoke plumes and puffs. The joint-venture Porton Down experiments, with international participation and support facilitated this objective. Modelling objectives included investigation and experimental evaluation of flow and diffusion modelling based on our LINCOM/RIMPUFF real-time codes.

With our high-resolution mini-lidar system, sequential measurements (1/3 Hz) were obtained of the instantaneous cross wind concentration profiles at fixed down wind distances from the source. The source consisted of ground level continuous smoke releases and elevated smoke puff releases.

The cross wind concentration profiles were measured with an effective spatial resolution of 1.5 meter.

From the conducted puff and plume diffusion experiments, we have by post-processing and data reduction obtained important concentration fluctuation statistics including:

Mean- and variance profiles, intermittency profiles, probability distribution functions, dispersion parameters (including instantaneous puff width). In addition we distinguish statistics obtained in a fixed frame (absolute diffusion), and center-of-mass frame (relative diffusion).

Derived statistics include:

Dispersion coefficients, and their dependence on sampling time (from instantaneous to length of experiments, typically 1-hour.)

Two-particle distance-neighbor functions yielding information about the instantaneous spatial correlation function of in-plume fluctuations.

Extreme statistics of exceedance of certain reference levels, and the (ensemble mean) duration of such exceedances.

Our Lidar based concentration fluctuation measurements were supported by our micro-meteorological observations from two tower mounted sonic anemometers, in addition to the joint mean wind and turbulence data gathered simultaneously by the participating groups at Porton Down.

### 1.3 Background

Within the CEC Radiation Protection Research Programme for Nuclear Safety, Risø is commissioned to conduct reference smoke plume dispersion experiments, where we based on the mini-LIDAR facility are studying concentration fluctuations for dispersion model evaluation and model uncertainty assessments. Also, we are conducting full scale reference and training experimental data for the CEC supported real-time decision support system RODOS, where atmospheric dispersion is a key element.

The layout and experimental set-up for the Porton Down MADONA experiments, including the many other participants, provided an unique opportunity to combine and jointly perform already scheduled uncertainty and evaluation experiments with the general objectives for MADONA.

Our entire scientific outcome from the smoke diffusion trial are consequently offered for inclusion in the MADONA data base, including the basic scientific analysis as described above.

All raw and statistical analyzed data from our LIDAR and micro meteorological measurements are shared. The latter includes 10-min mean and turbulent scaling parameters such as variances, energies, shear stress and heat flux (Monin-Obukhov length).

### 1.4 Reporting and Availability of Results

This data report describes the experimental setups, time periods and atmospheric conditions for the MADONA trials.

Our final results are given in the included 4 papers to be presented at the 11th AMS Boundary Layer and Turbulence symposium in Charlotte, NC, USA during the period 27-31 March 1995.

## 1.5 Acknowledgements

Risø obtained additional financial support for expenses associated with moving our experimental facilities and personnel to Porton Down, UK.

Our participation in the MADONA trials were hereafter made possible by support from the CEC Radiation Protection Research Programme, DGXII, under contract No. BI7-0017-C, and by a grant from the US Army Research Branch, London, under contract No. DAJA45-92-M-0344. Mr. Ron Cionco at the U.S. Army Atmospheric Science Laboratory, White Sands, MN., USA and Mr. Jerry Comati at the US Army Research Branch, London, are gracefully acknowledged.

## 2 Technical Description

### 2.1 Mean and Turbulence Measurements from two Micro-Meteorological Masts

Two 7 meter high meteorology mast were erected and instrumented at the Porton Down site near the Westerly source point, see Fig. II.1. (Porton Down landscape seen from South-West.)

The met-towers were each equipped with Kaijo Denki DAT 300 sonic anemometers in order to obtain both mean-profile and turbulence scaling parameters for the MADONA dispersion trials.

**Appendix II.1:** Contains directly measured mean and turbulence quantities, including: 1) Mean Wind speed, 2) Direction, 3) Turbulent Kinetic Energy, 4) Stress, 5) Sensible Heatflux, 6) Monin-Obukhov Stability parameters and 7) Temperature statistics.

**Appendix II.2** Comparison between 5 and 10 min averaged statistics for day: 23/9 192; sonic 1 and sonic 2.

The measurements were obtained from two acoustic three-dimensional sonic-anemometer/thermometers (Kaijo Denki type DAT-300), located at 7 meter level above the floor.

Running continuously during the entire experimental campaign, they provided us with real-time, on-line surface layer turbulence statistics of the most important scaling parameters for dispersion. By use of our PC-based on-line data acquisition system and associated computers, we measured and calculated (in real-time) the entire co-variance matrix of the fluctuating quantities  $u'$ ,  $v'$ ,  $w'$  and  $T'$  (by the correlation-method), and from here, the velocity and temperature intensities, the shear-stress and the sensible heat flux was deduced at 10-min intervals in real time. With the additional information of the inversion height from rawin-sonde balloons (not provided by Risø), the sonic anemometer data enables us to calculate the very important scaling parameter for convective conditions:  $W_{*}$ .

Our sonic-based on-line "turbulence monitoring-system" provides the experimenters and the project-manager with real-time measurements of the atmospheric stability and turbulence state at Porton Down, concurrently with each diffusion test and provided also direct measurements of the variances and fluxes requested for the subsequent model evaluation study.

The Risø Sonic-DAS-system was put in continuous operation throughout the whole experimental period. Our directly measured, 10-min averaged quantities included:  $\langle u'u' \rangle$ ,  $\langle u'v' \rangle$ ,  $\langle u'w' \rangle$ ,  $\langle u'T' \rangle$ ,  $\langle v'v' \rangle$ ,  $\langle v'w' \rangle$ ,  $\langle v'T' \rangle$ ,  $\langle w'w' \rangle$ ,  $\langle w'T' \rangle$ ,  $\langle T'T' \rangle$ , in addition to the mean wind speed and mean temperature.

The accuracy of the sonic anemometer/thermometer type DAT 300 is, according to the manufacturer (Kaijo Denki Co.):  $\pm 1\%$  on measured velocity and temperature signals, the resolution is 0.5 cm/s and 0.025 K, respectively. It measures all signals 20 times per second and has a 10 Hz low-pass output filter. For measurements taken 7 meter above the ground, this instrument will provide very adequate resolution of the turbulent signals, both with respect to spatial and temporal resolution: The on-line data acquisition system (DAC\_SYS) point-samples the four signals U,V,W and T at a rate of 10 Hz, and subsequently calculates the co-variance matrix after each 10-min period based on the corresponding 6000 readings of each signal.

The directly measured time series (consisting of four times 6000 measurements each per 10-min period) are also stored for subsequent spectral analysis.

Data-, both mean and of the turbulence quantities, have already been processed, stored and backed-up as 10-min average quantities. Additional to visual inspection of raw time series, more objective quality assurance in accordance with Højstrup, 1993 will be performed on central data periods.

## 2.2 High-Resolution Time-Series and Spectral Analysis

Additional spectral analysis can at request be performed on 10-min average meteorological quantities. For each of the scheduled diffusion tests, the following is available on request:

1. Time series plots of high-resolution (10 Hz) wind and temperature signals from the sonic anemometer.
2. Time series of short-time averaged (1-min running mean) quantities of wind speed, direction, turbulence level, shear stress and heat flux.
3. Spectral analysis of the three wind ( $u'$ ,  $v'$ ,  $w'$ ) and temperature ( $T'$ ) signals.

This information is of importance in a subsequent modelling evaluation. in particular for:

- I Gaining insight into the fine scale temporal evaluation of the boundary flow and turbulence in the valley during each diffusion test.
- II gaining insight into which turbulent scales are of importance and most energetic, and consequently responsible for the exchange and diffusion processes, and
- III Providing detailed turbulence measurements at the source point for use in the subsequently planned model simulation of the experiments.

We provide on request, for each of the successfully performed diffusion tests:

- re i. 10-Hz digitized raw data of U,V,W and T on PC-diskette.
- re ii. Time series plots of sonic data and of the corresponding 1-min running mean turbulence quantities.
- re iii. Plots of the three velocity spectra and the temperature spectrum from 0.001 to 5 Hz.

### 3 LIDAR-Measurements of Surface-Released Smoke Plumes

The Risø National Laboratory operates a mini-LIDAR system for determination of instantaneous concentration profiles inside dispersing aerosol-plumes.

The system yields high spatial and temporal resolution measurements of in-plume concentration fluctuations, from which important and basic scientific plume dispersion characteristics can be inferred.

For the MADONA trials, we provided a powerful and sturdy artificial smoke generator, which produced ground-level releases of smoke plumes or elongated puffs.

The smoke consisted of non-toxic white plume of sub-micron aerosols. The aerosols were conglomerated  $\text{SiO}_2$  and  $\text{NH}_4\text{OH}$  that is detectable by our 1.064  $\mu$  lidar system. In this way, measurements of the cross-wind near-ground concentration profiles were obtained at various distances downwind.

During evenings and nights with stable atmospheric conditions, the lidar system can pick up the smoke plume concentrations out to several kilometers from the source point.

At Porton Down, the mini-LIDAR system measured instantaneous "snapshots" every 3. or 5. second of the aerosol back-scatter cross-section.

**Appendix III.1:** Contains information of lidar positions and measurement periods obtained at the MADONA trials. It includes also drawings of source and lidar positions for the total of 23 experiments. See also RUN\_DOC Appendix IV.

**Appendix III.1:** LIDAR scanned mean concentrations from MADONA experiment No. 22f (1 hour 22 min continuous release).

**Appendix III.2a-d:** From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in fixed frame (meander included).

**Appendix III.3a-d:** From Madona exp. No. 15h: Lidar measured mean, variance, fluctuation intensity and intermittency crosswind profiles in moving frame (meander removed).

The measurements related to the number of aerosols in the small measurement volume, which is a "cigar-shaped" cylinder of approx. 1 meter in diameter and approx. 1.5 meter long.

Extensive data-processing of the raw lidar-signals is in progress in order to produce accurate and quality-assured cross-wind aerosol concentration profiles. In return, we obtain from each experiment, not only the mean concentration profile, but also a measure of the natural fluctuation and inherent uncertainty associated with dispersion. This is of importance for subsequent model evaluation studies.

During madona, we obtained both stable, neutral and unstable experiments based on both plume and puff releases. The release rate of the aerosol generator was kept constant during individual experiments.

Our contribution to the MADONA data base contains, for each experiment:

- 1) Time series of cross-wind profiles
- 2) Plots of mean cross-wind concentration
- 3) Plots of fluctuating (rms)
- 4) Plots of in-plume intermittency
- 5) Measurements of the entire measured concentration pdf (probability density distribution) from which, for instance, different exceedance statistics and high-level exposure events can be inferred.

The posterior data processing, reduction and analysis of our Lidar-activity is rather involved, and will require between 6 and 12 month of data preparation and analysis following the experiments to finalize.

## 4 Modelling

### 4.1 Mean-Flow Modelling: Real-Time Diffusion Model Simulations

The local-scale real-time dispersion modelling system LINCOM/RIMPUFF is evaluated using data from the complex terrain Guardo experiments carried out in Northern Spain November 1990.

Releases of tracer gas ( $\text{SF}_6$ ) were simulated from a 185 m tall buoyant power plant stack, and from a valley floor release (10 m). The observed wind flow and plume diffusion is modelled and compared with tracer gas measurements. Studies reported in this paper include one daytime up-valley breeze situation and one nighttime down-valley drainage flow situation.

Wind and turbulence data were obtained from a network of 9 meteorological towers over the 40x40 Km experimental domain, accompanied by balloon and acoustic soundings.

The study shows that a linearized dynamic flow models, when properly initialized (assimilated) by observations, is an attractive alternative to the diagnostic mass consistent models for real-time applications.

Simulations of the airflow and diffusion over the MADONA topography were made with a variety of models. Several simulations were made on-site and in real-time, while others were made after the experiment during the analyses of the observed wind and diffusion pattern. Wind fields and wind-related parameters were simulated with high resolution wind models such as HRW, Ball and Johnson and LINCOM.

LINCOM is a non-hydrostatic diagnostic model based on the solution of linearized continuity and momentum equations with a first order spectral turbulent diffusion closure. It processes a single layer of 100x100 grid points in less than 10

seconds on a 486 IBM compatible PC. Its truncated physics of course restricts its application over severe non-uniform terrain, but considerable realism in the flow fields was achieved by use of assimilation techniques to match results to measured tower or forecast winds.

The puff diffusion code RIMPUFF is designed for real-time episode modeling of hazardous cloud dispersion during time and space changing meteorology. The model is provided with a puff splitting feature to handle plume bifurcation and shear flow over non-uniform terrain. The puff growth process is controlled by local turbulence levels, derived from on-site measurements.

Diffusion of smoke and tracer gas was calculated by RIMPUFF using the wind fields calculated by LINCOM. Several MADONA experiments have been simulated with RIMPUFF and other diffusion models. Results are compared using various qualification factors: relative Chi square, correlation factor and mean error factor.

In connection with our on-going activities with the CEC-RODOS activities for real-time on-line decision support, we additionally setup our modelling system LINCOM/RIMPUFF at the MADONA site:

For mean-flow wind field calculations at the Porton Down experimental area, we have setup our fast PC-version of LINCOM to calculate winds over the experiment site at various heights and for different synoptic wind directions. LINCOM is a non-hydrostatic spectral, neutral wind code, cf. Santabarbara (1993).

LINCOM is setup to run based on the measured tower winds and as such, it is suitable as driver for dispersion studies over complex terrain. Alternatively, the model can run on a single wind speed and direction as input, if the dominating winds are driven by synoptic forces.

Our studies include comparison of measured tower winds with model results based on single inputs, the MADONA study with several wind observations are unique for this model/data intercomparison.

At present this flow model is under development in order to incorporate the effect of thermally driven forcing such as night-time drainage flows and day-time up-valley breezes. Since this model is as central as a "driver" for our puff-dispersion model RIMPUFF in complex terrain, it is worthwhile to test its applicability for the Porton Down terrain in question, - and possibly even use the obtained results from these experiments in order to evaluate our efforts regarding improving the model to include the effects of thermal forcing.

## **4.2 Combined Mean-Wind and Dispersion Models for Real-Time Plume Dispersion Assessment over Undulating Terrain**

Our dispersion modelling work is centered about a Lagrangian Mesoscale Puff-diffusion model (RIMPUFF), which over the years has obtained acknowledgement and use internationally, for instance in the UFOMOD and the COSYME consequence assessment systems available in public domain by the CEC. For dispersion calculations over complex terrain, the PC-based RIMPUFF model is presently twinned with the non-hydrostatic mean flow model LINCOM, which is based on the Navier-Stokes equations for motion, including mass, momentum and heat conservation. The combination of the flow and diffusion model results in an extremely fast computer code, which advantageously can be tested and evaluated in real time with experimental data from the present diffusion experiments.

A modelling effort based on selected MADONA diffusion trials is consequently in progress.

- Appendix IV:** Contains the first preliminary model results of wind and diffusion calculations from the MADONA trials: Sep 17, release time 11:10 - 16:10.
- Fig. IV.1:** Shows LINCOM output of hourly consecutive wind field calculations based on tower data inputs.
- Fig. IV.2:** Shows detailed stream line plot of one of these wind fields, including tower wind data???
- Fig. IV.3:** Shows instantaneous plume positions at ten minute intervals and also total integrated concentration (dose).
- Fig. IV.4:** Porton Down terrain vertical magnified x 20 seen from south-west
- Fig. IV.5:** Example of tower data representation for Lincom inputs.
- Fig. IV.6:** Example of Lincom grid wind field (10 meters height) 300 meter horizontal resolution
- Fig. IV.7:** As Fig. IV.6, 100 m horizontal resolution.
- Fig. IV.8:** Example of stream line wind field from neutral LINCOM (10 meters height) at Porton Down terrain.

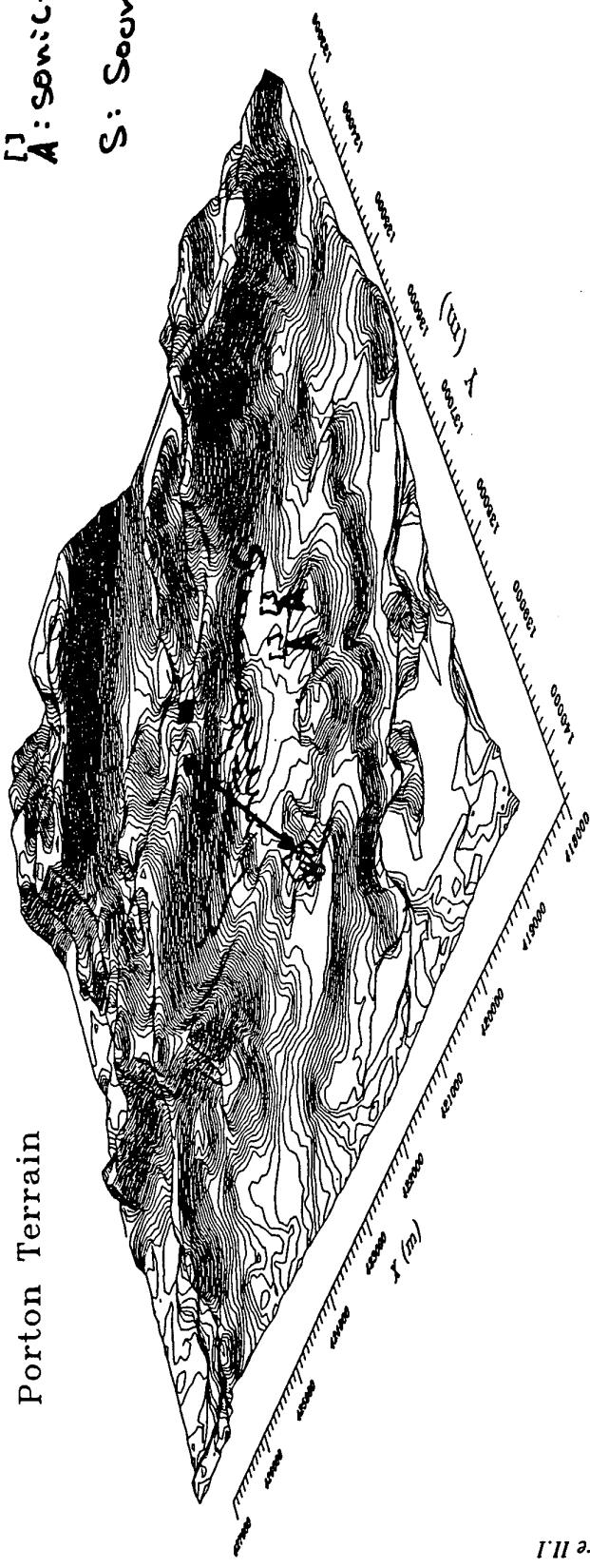
## References

(Highlighted References are fully included at the end, Appendix IV)

- Cionco R.M., W. aufm Kampe, C. Biltoft, J.H. Byers, C.G. Collins, T.J. Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, D.J. Ride, R. Robson, J.M. Santabarbara, J. Streicher, S. Thykier-Nielsen, H. van Raden, H. Weber (1995): An overview of MADONA: A multi-national field study of high-resolution meteorology and diffusion over complex. In: Proceedings of the 11th Symposium on Boundary Layers and Turbulence, Charlotte, N.C., USA, March 1995, pp. 306-311. (Submitted to: *Bulletin of the American Meteorological Society*).
- Jørgensen, H.E., T. Mikkelsen, D.J. Ride, T. Higgs, C.J., W. aufm Kampe, H. Weber, K. Nyrén and P.E. Johansson (1995): MADONA: Concentration fluctuation analysis. In: Proceedings of the 11th Symposium on Boundary Layers and Turbulence, Charlotte, N.C., USA, March 1995, pp. 306-311.
- Mikkelsen, T. and H.E. Jørgensen (1995) MADONA: On-site real-time turbulence measurements. In: Proceedings of the 11th Symposium on Boundary Layers and Turbulence, Charlotte, N.C., USA, March 1995, pp. 445-448.
- Mikkelsen, T., H.E. Jørgensen, K. Nyrén and J. Streicher (1995). MADONA: Diffusion measurements of smoke plumes and of smoke puffs. In: Proceedings of the 11th Symposium on Boundary Layers and Turbulence, Charlotte, N.C., USA, March 1995, pp. 319-322.


- Santabárbara, J.M., J. Calbo, J.F. Harnández, T. Mikkelsen and J.M. Baldasano (1995). Wind Flow over Complex Terrain (*MADONA*): A Comparison of three State-of the Art Models and Full-Scale Observations. To be presented at the 21. International Technical Meeting on Air Pollution Modelling and Its Application, Baltimore, USA, 6-10 November, 1995.
- Ride, D.J., W. aufm Kampe, C. Biltoft, J.H. Byers, Cionco R.M, C.G.Collins, T.J.Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, R.Robson, J.M. Santabarbara, J. Streicher, S. Thykier-Nielsen, H. van Raden, H. Weber (1995): *MADONA*, the high-resolution data set from trial *MADONA* (Meteorology and Dispersion over NON-uniform Areas). Version 2. Available from: CBDE-Porton Down, Salisbury, England, 1 CD ROM.
- Thykier-Nielsen, S, T. Mikkelsen, J.M. Santabarbara, D.J. Ride, T. Higgs and H. Weber (1995 a). *MADONA*: Real-time diffusion model simulations. In: Proceedings of the 11th Symposium on Boundary Layers and Turbulence, Charlotte, N.C., USA, March 1995, pp. 327-330.


Figure 11.1



Porton Terrain

 : Lidar

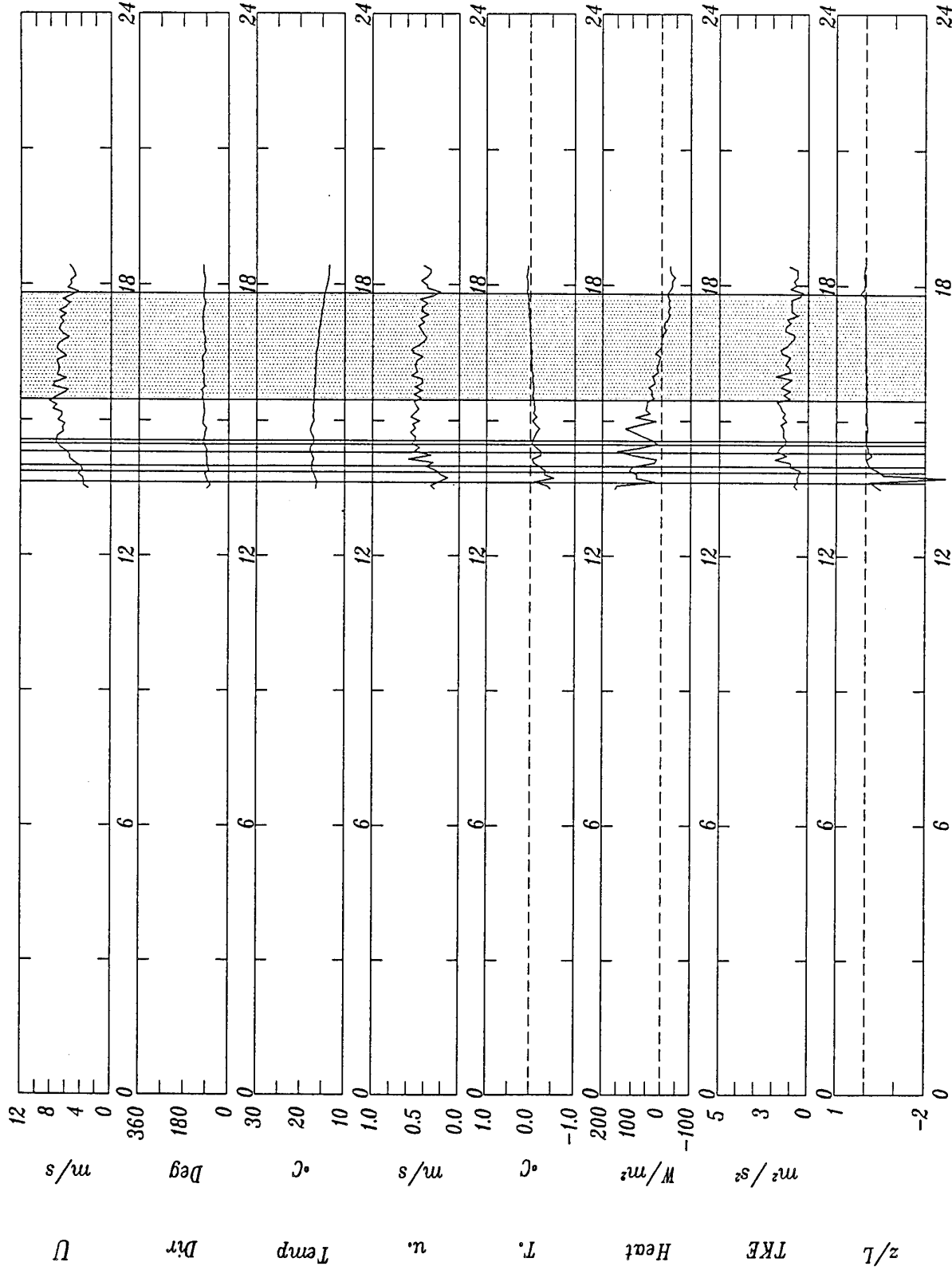
 Hard Target.

 A: Sonic-Rise.

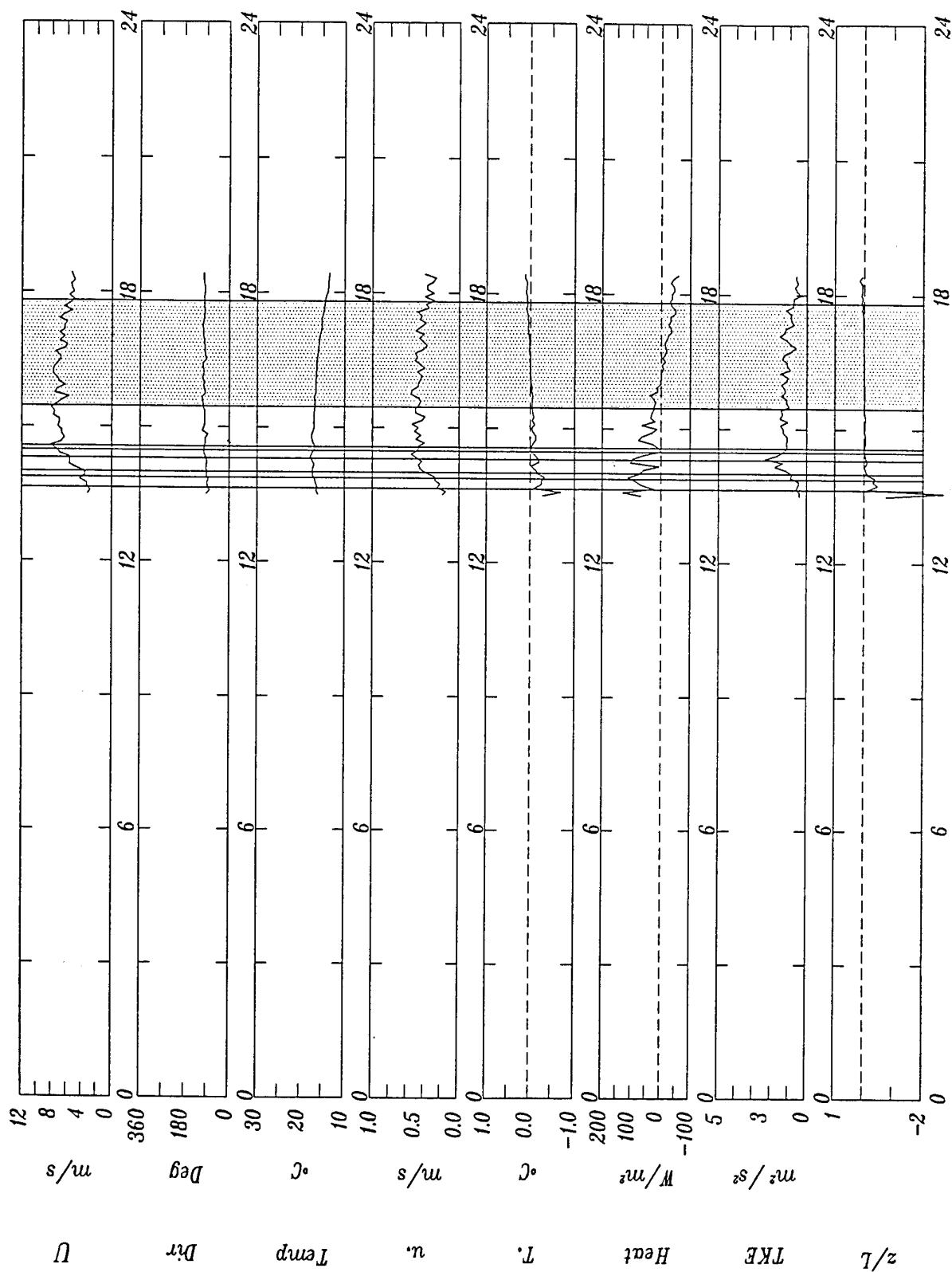
S: Source

# Appendix II

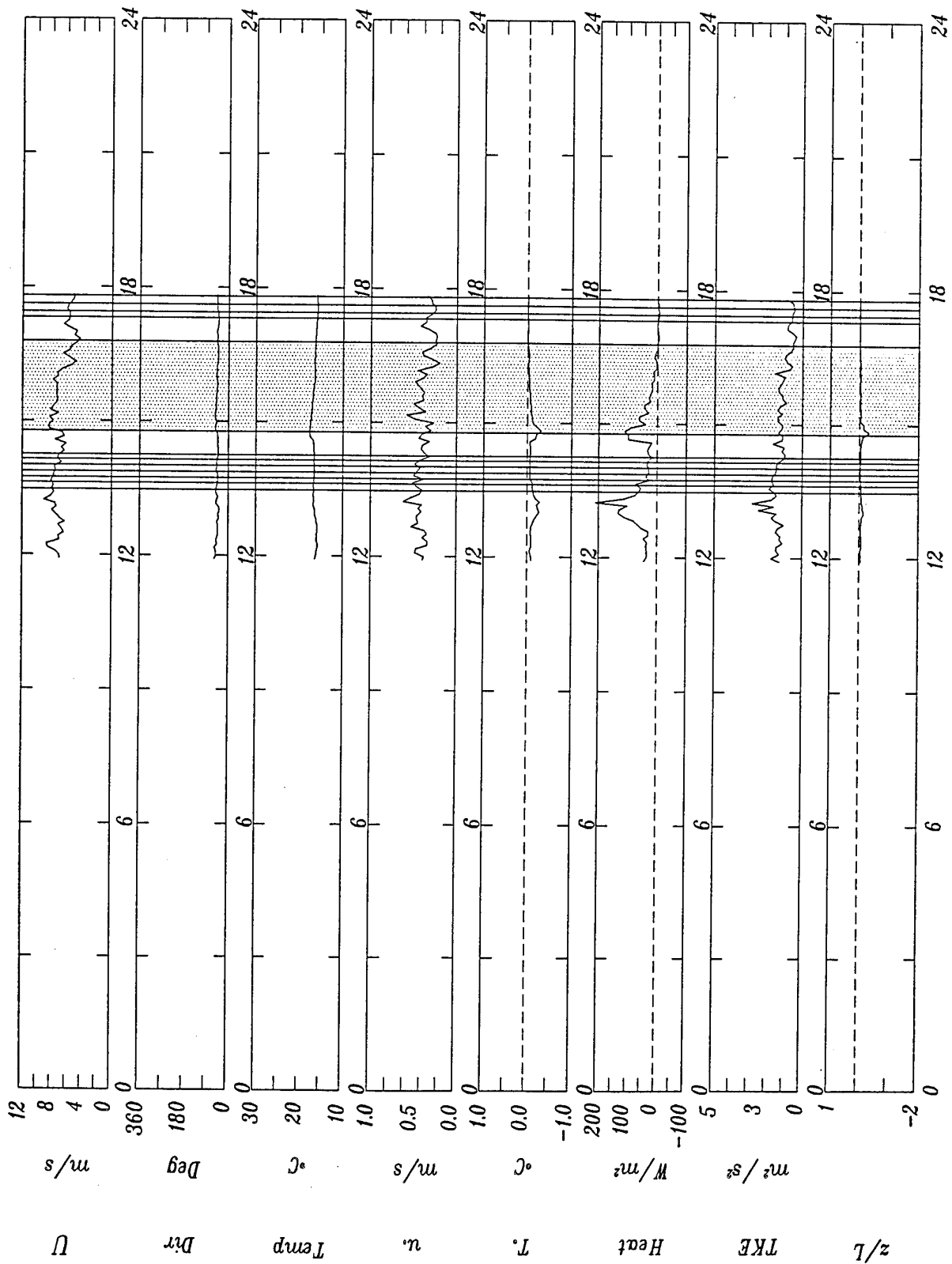
Sonic 1 micromet: 920914 MADONA



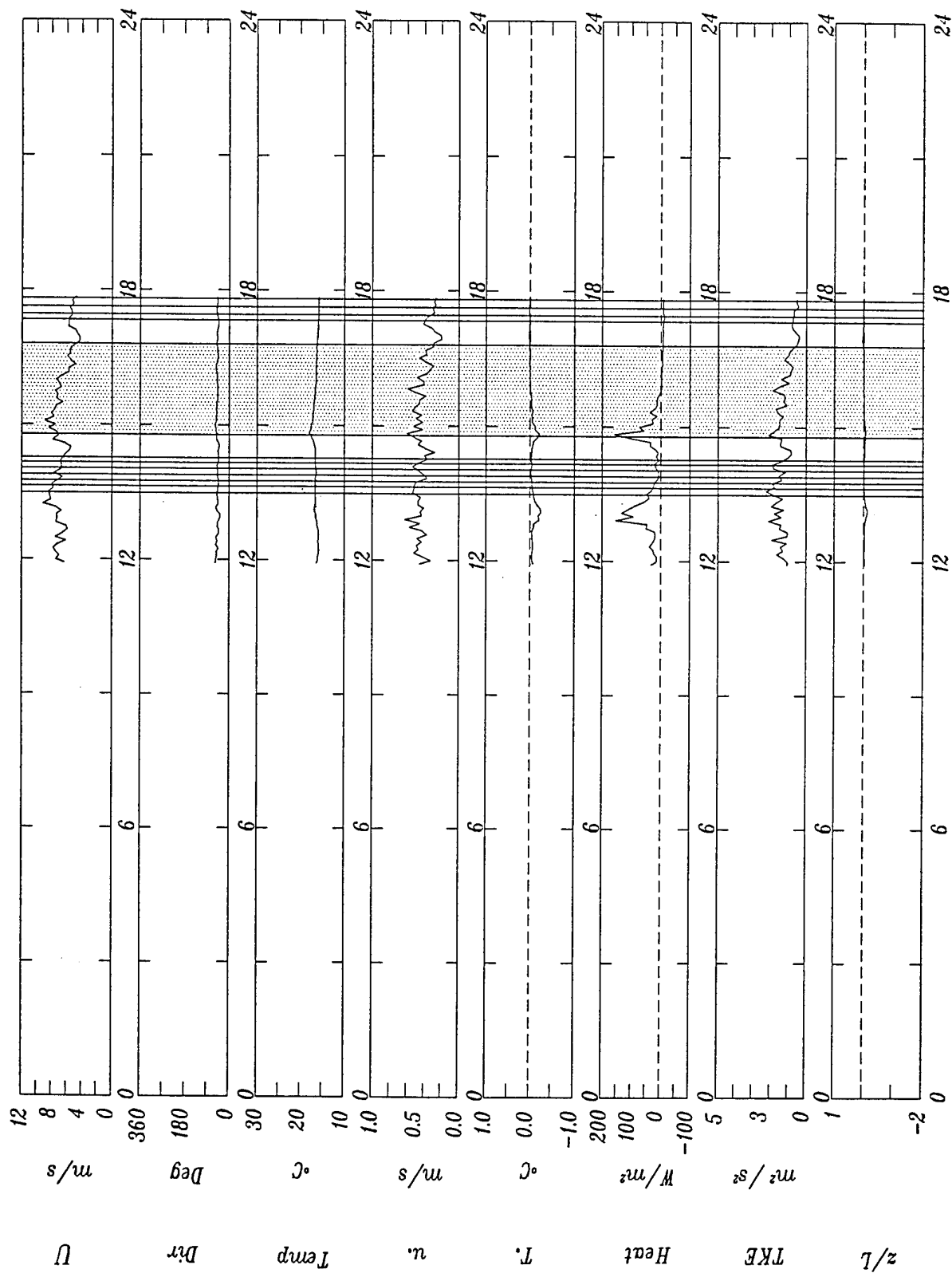
# Sonic 2 micromet: 920914 MADONA



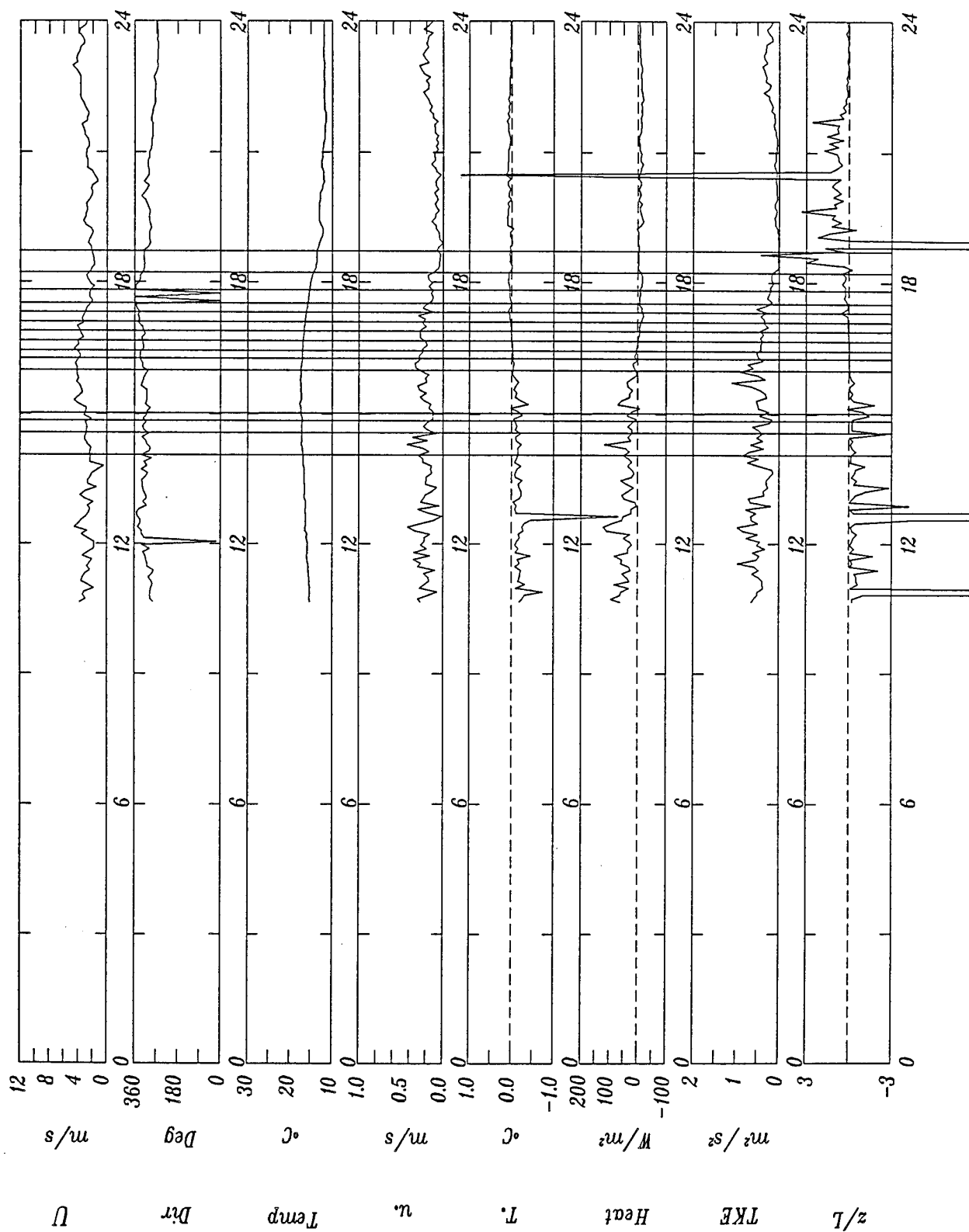
# Sonic 1 micromet: 920915 MADONA



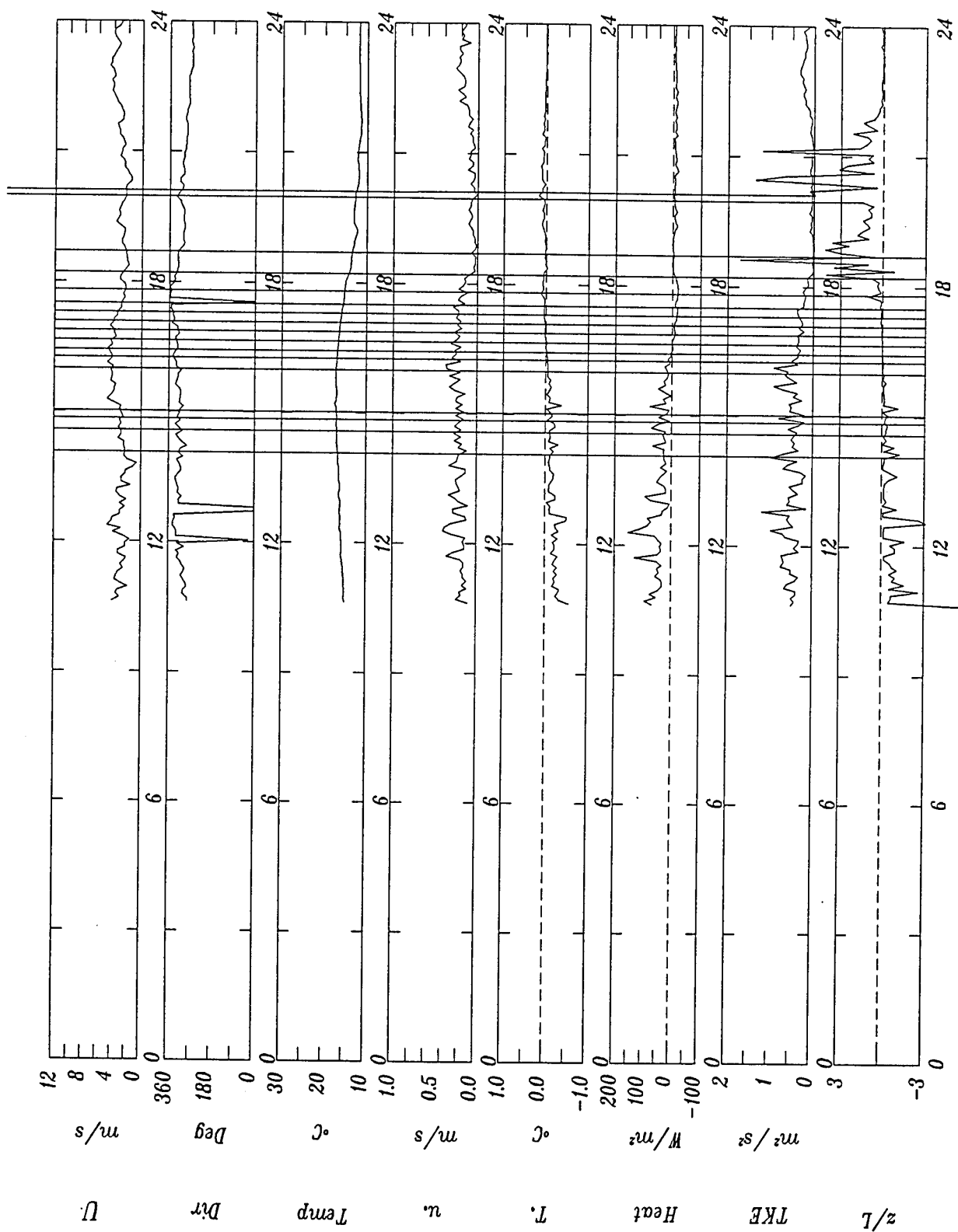
# Sonic 2 micromet: 920915 MADONA



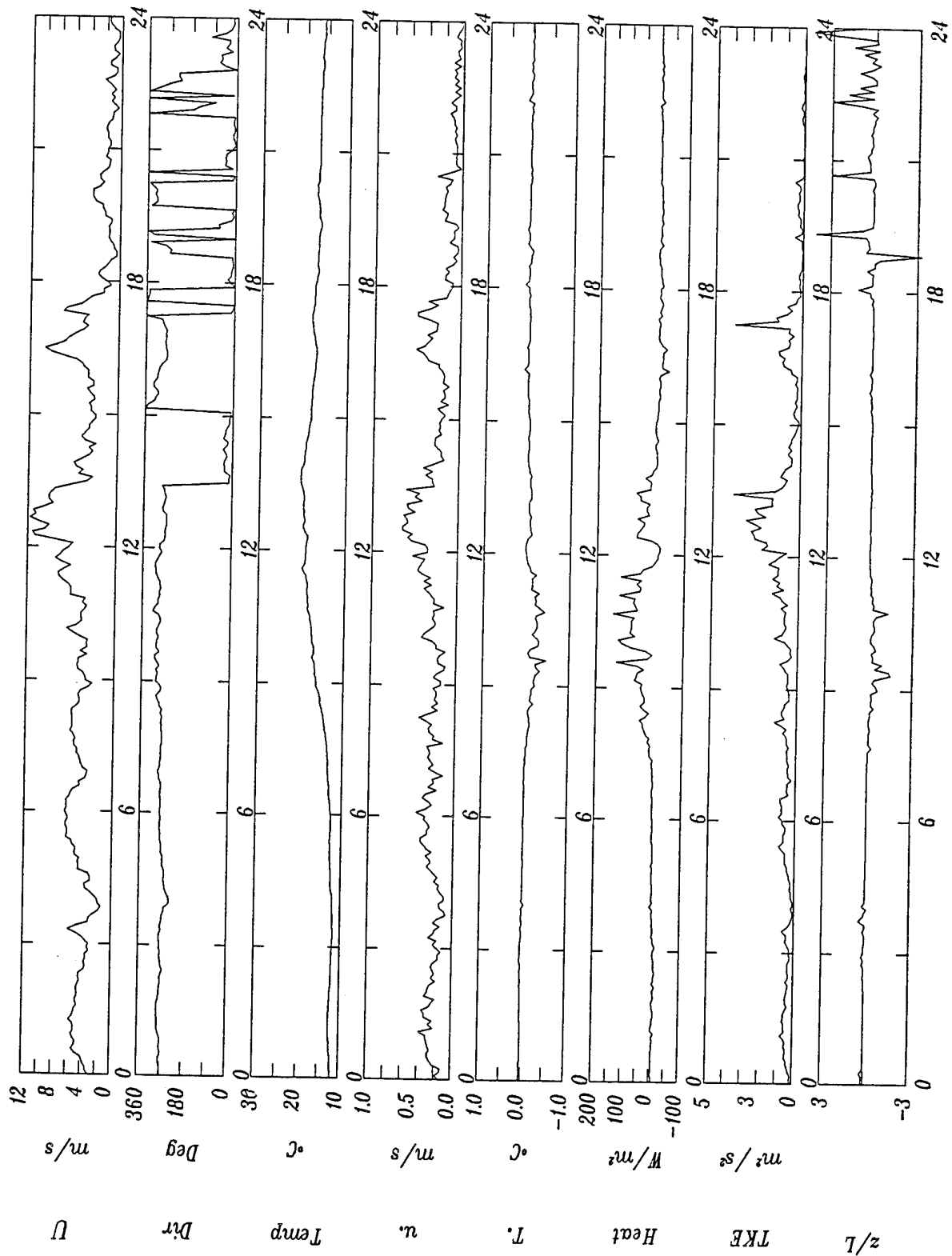
# Sonic 1 micromet: 920916 MADONA



# Sonic 2 micromet: 920916 MADONA



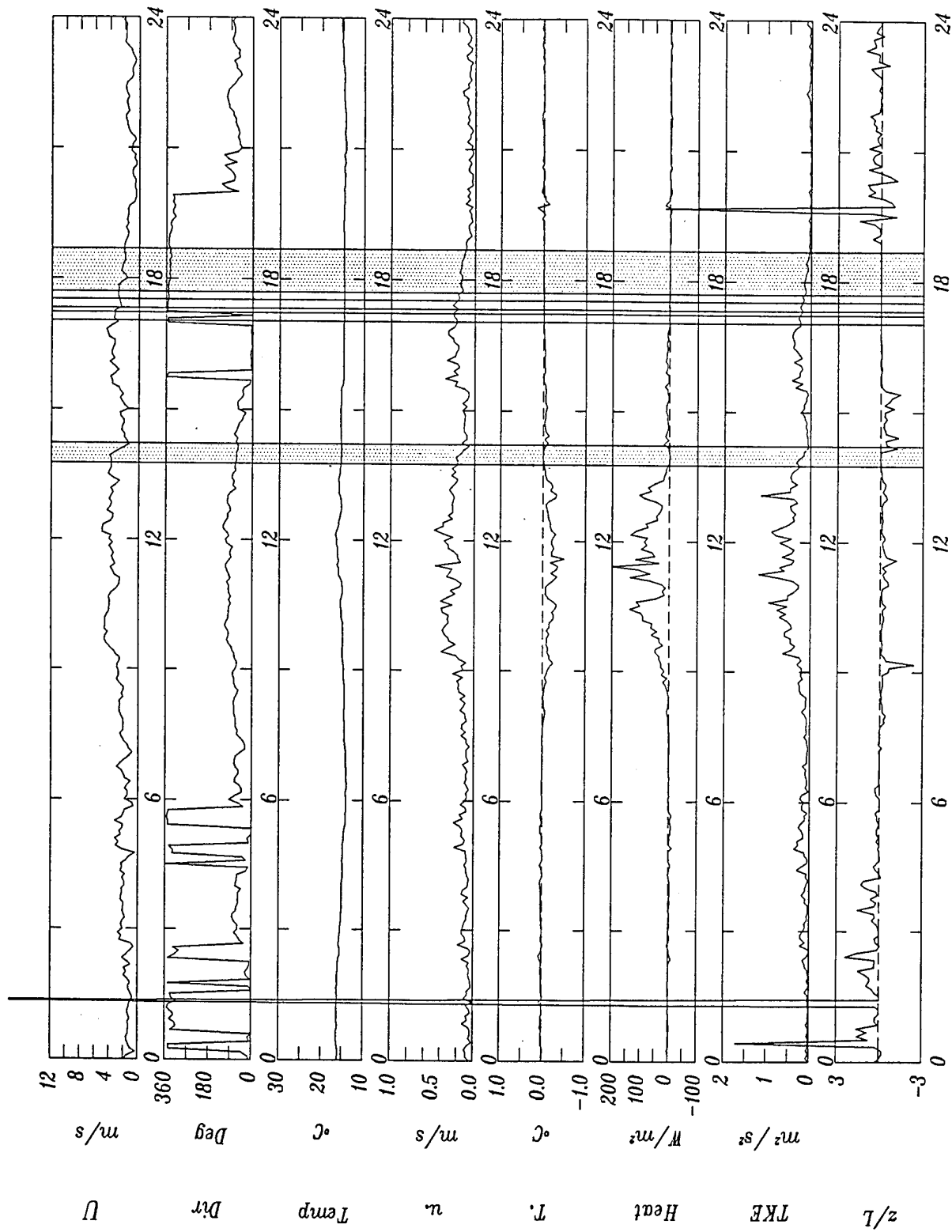
Sonic 1 micromet: 920917 MADONA



Risp-R-852(EN)

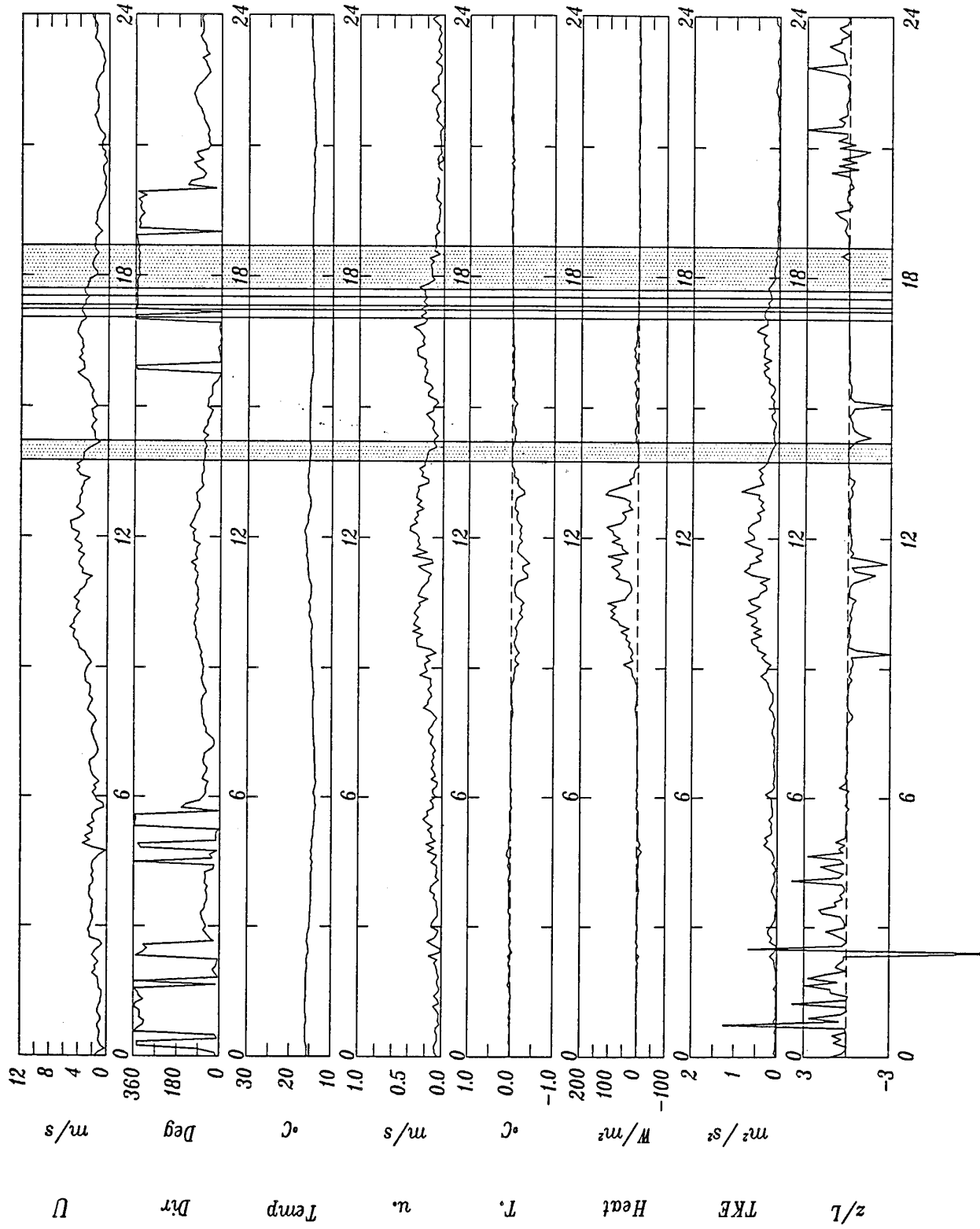
Figure II.1

Sonic 1 micromet: 920918 MADONA



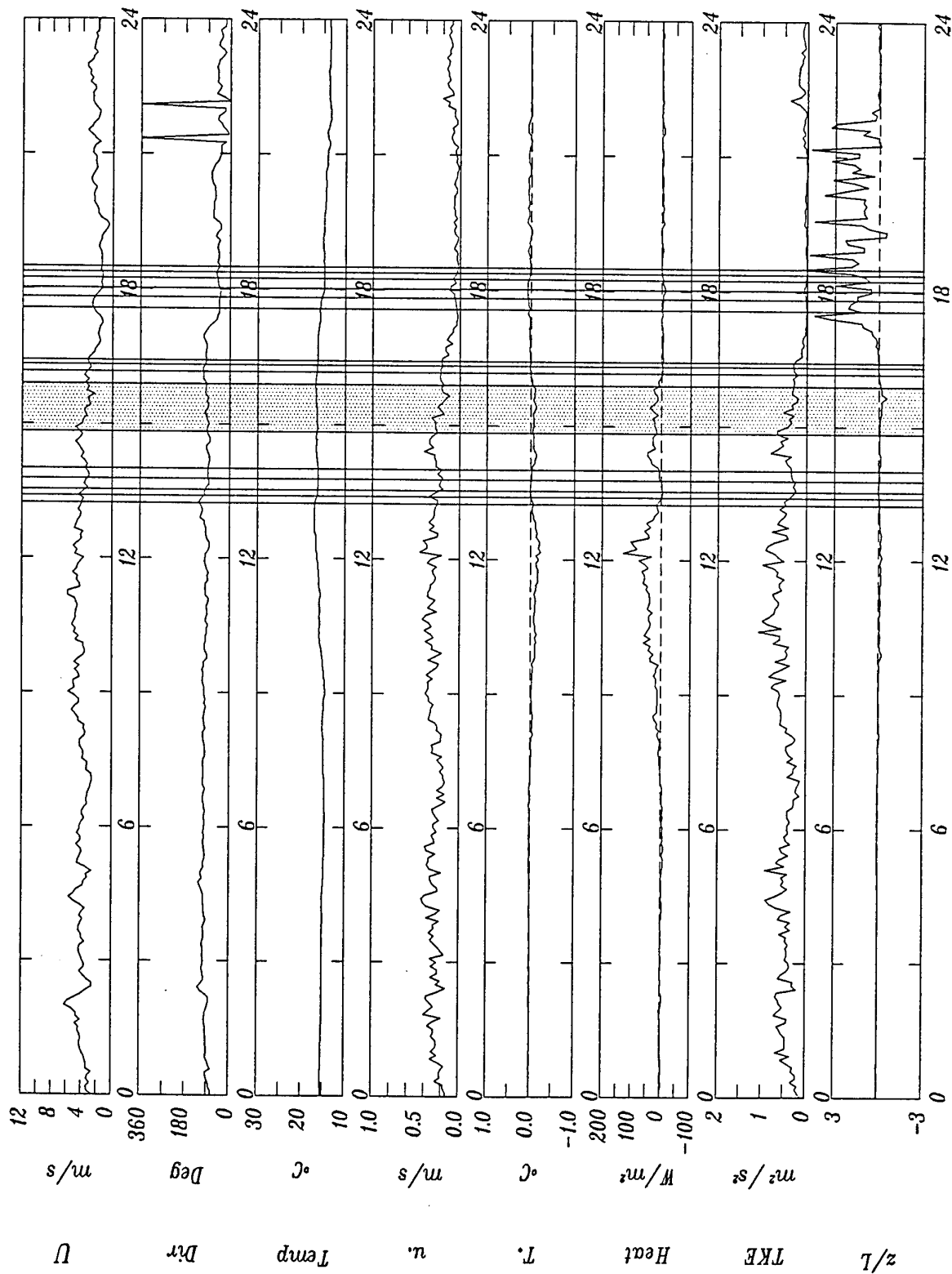
# Appendix II.1

Sonic 2 micromet: 920918 MADONA

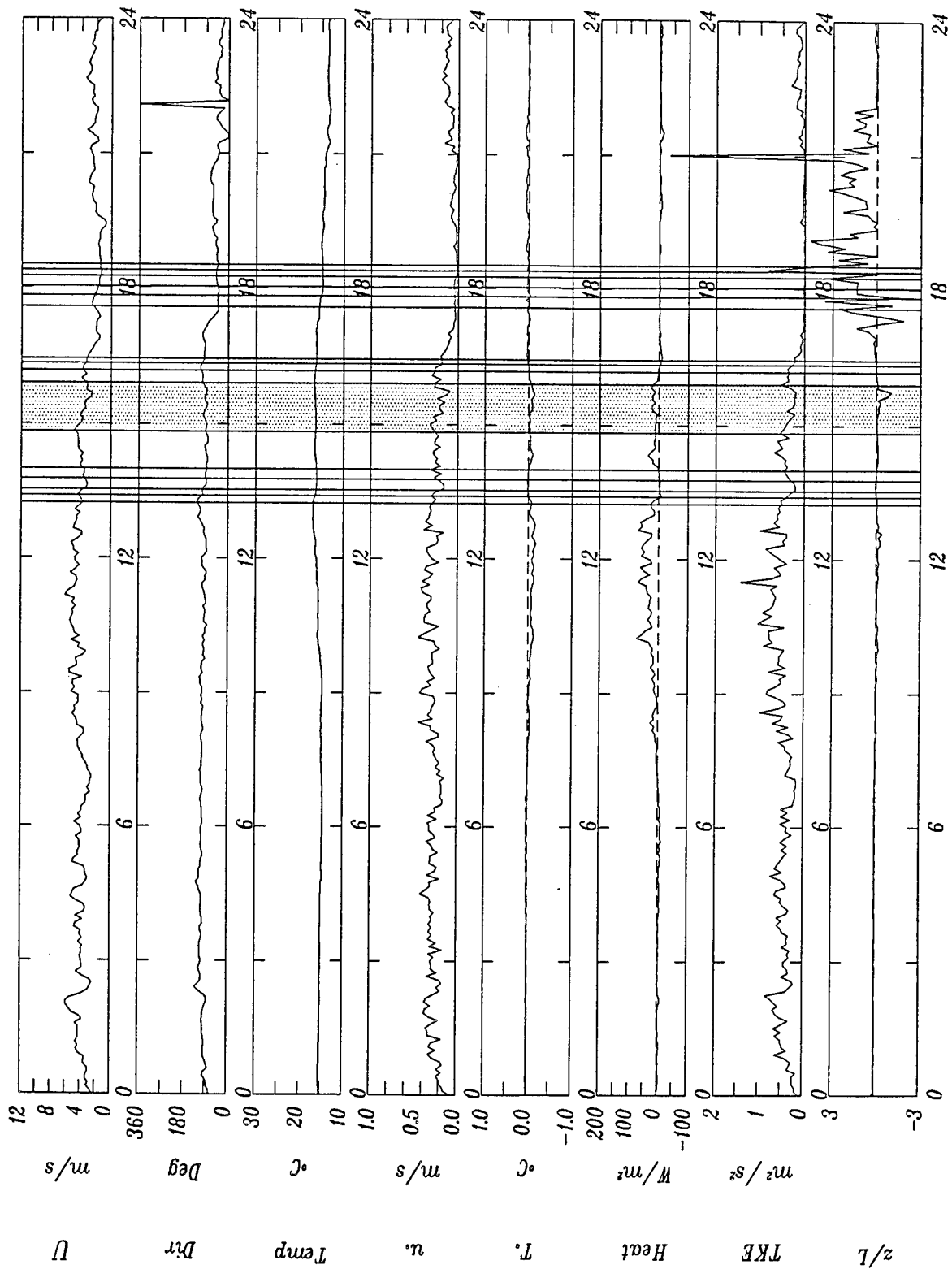


Risø-R-852(EN)

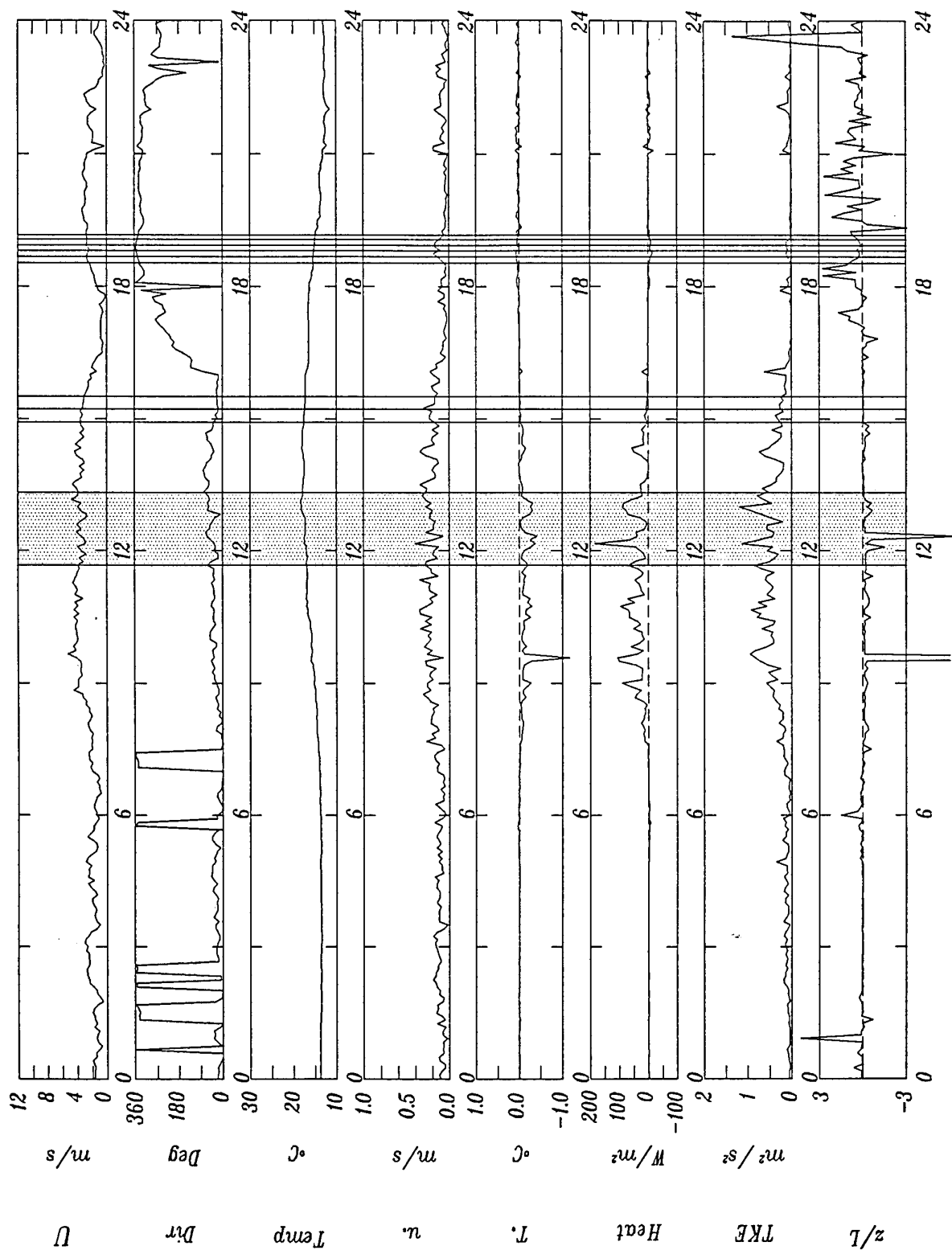
# Sonic 1 micromet: 920919 MADONA



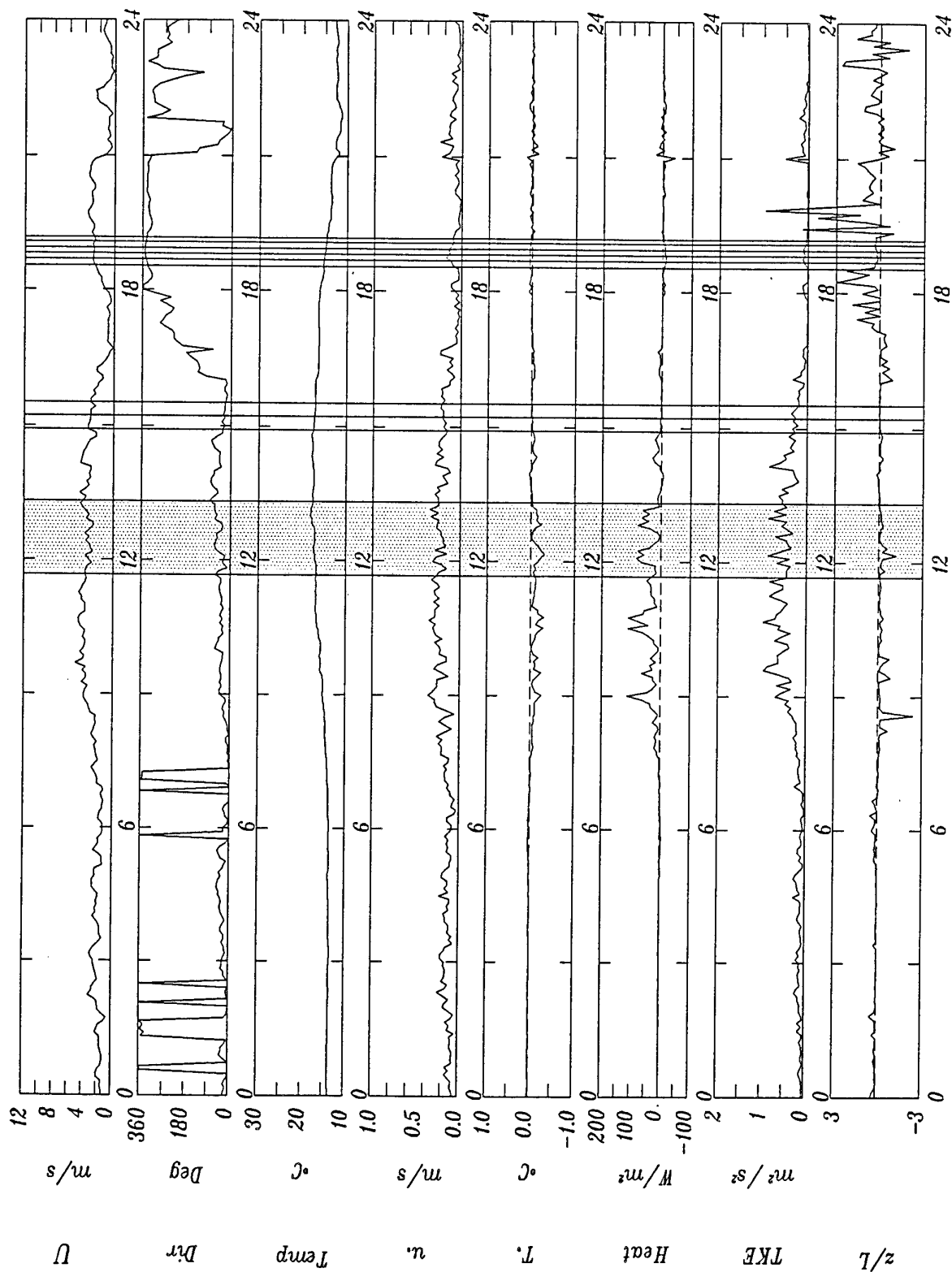
# Sonic 2 micromet: 920919 MADONA



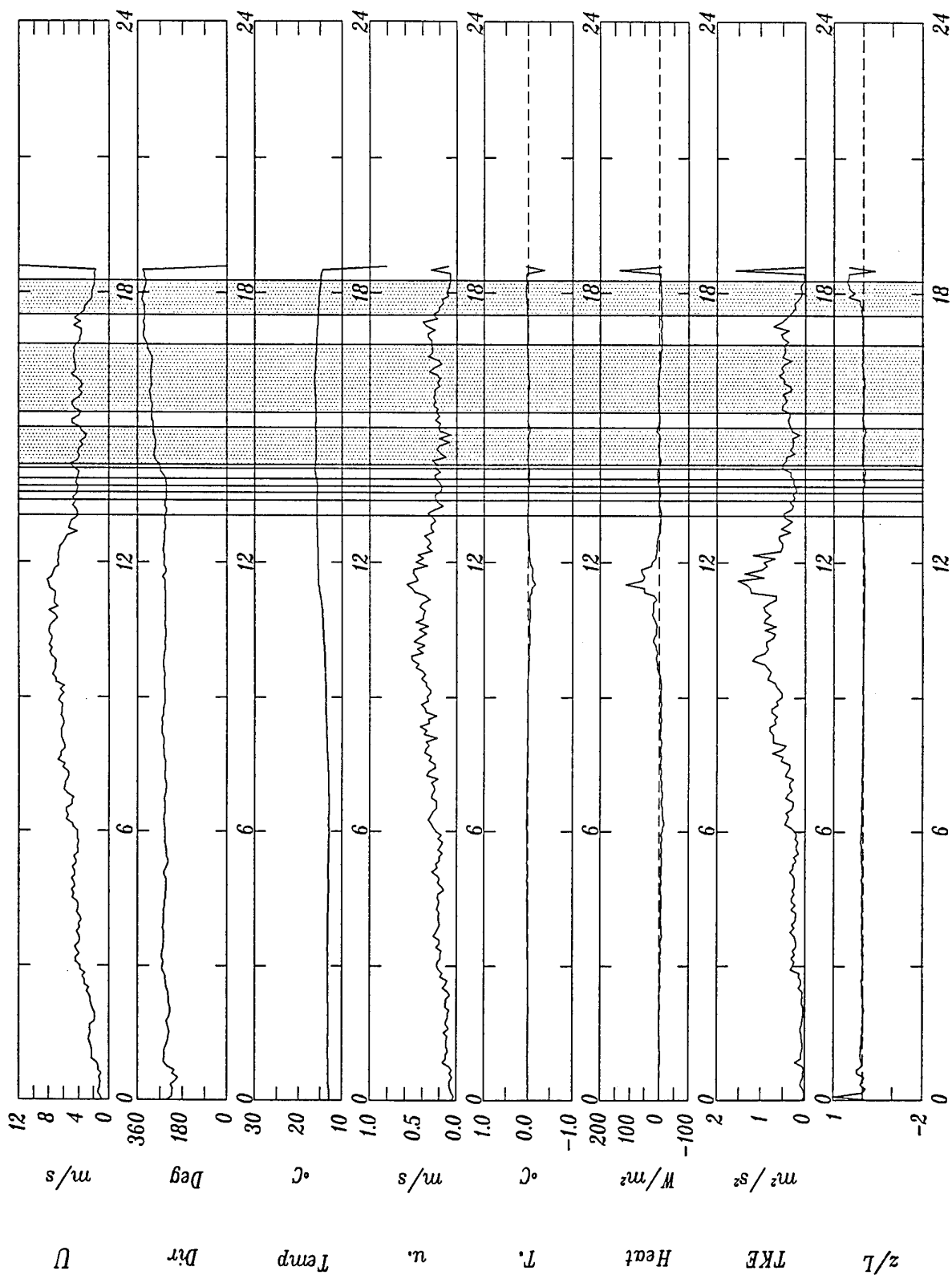
# Sonic 1 micromet: 920920 MADONA



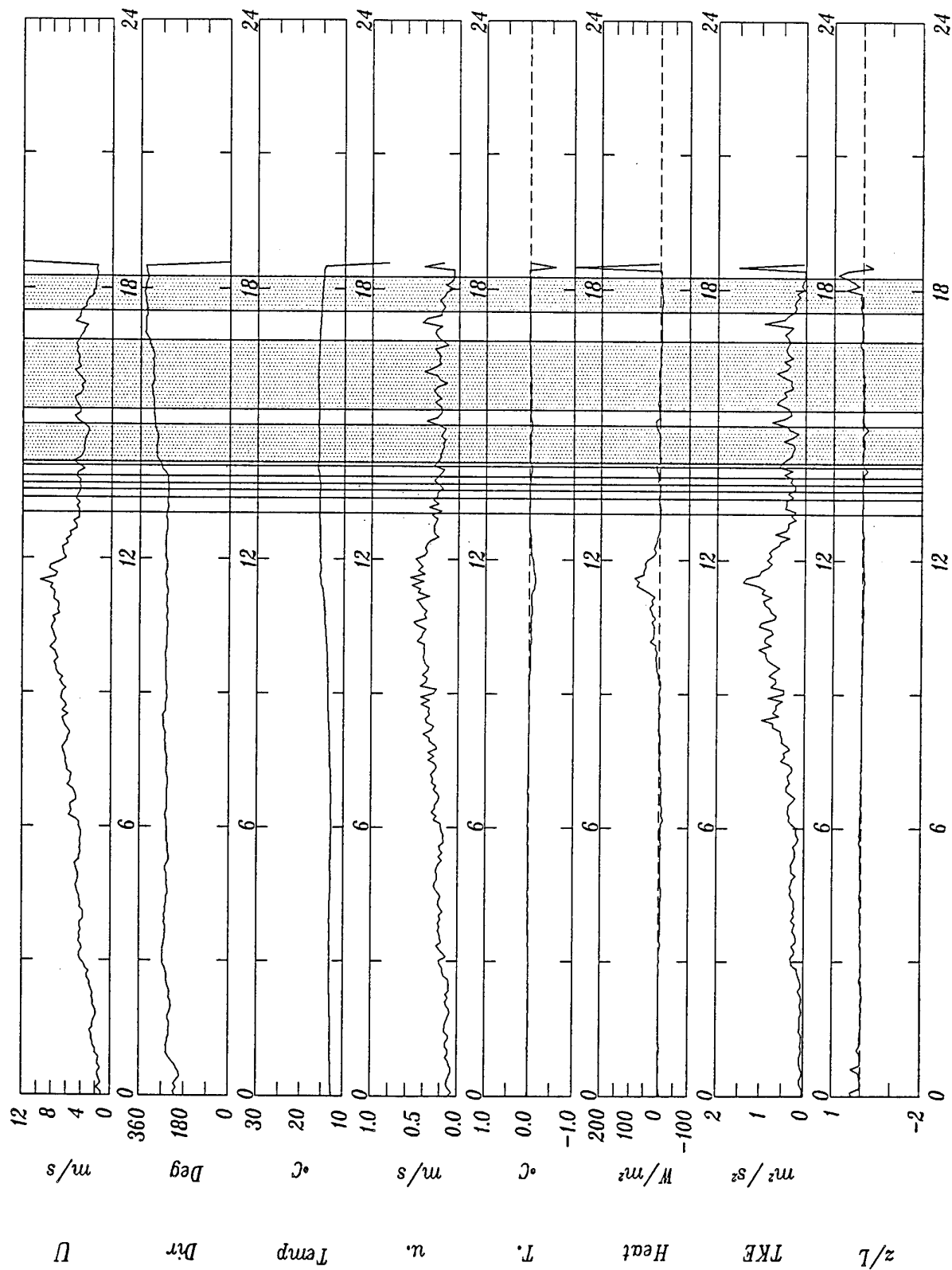
# Sonic 2 micromet: 920920 MADONA



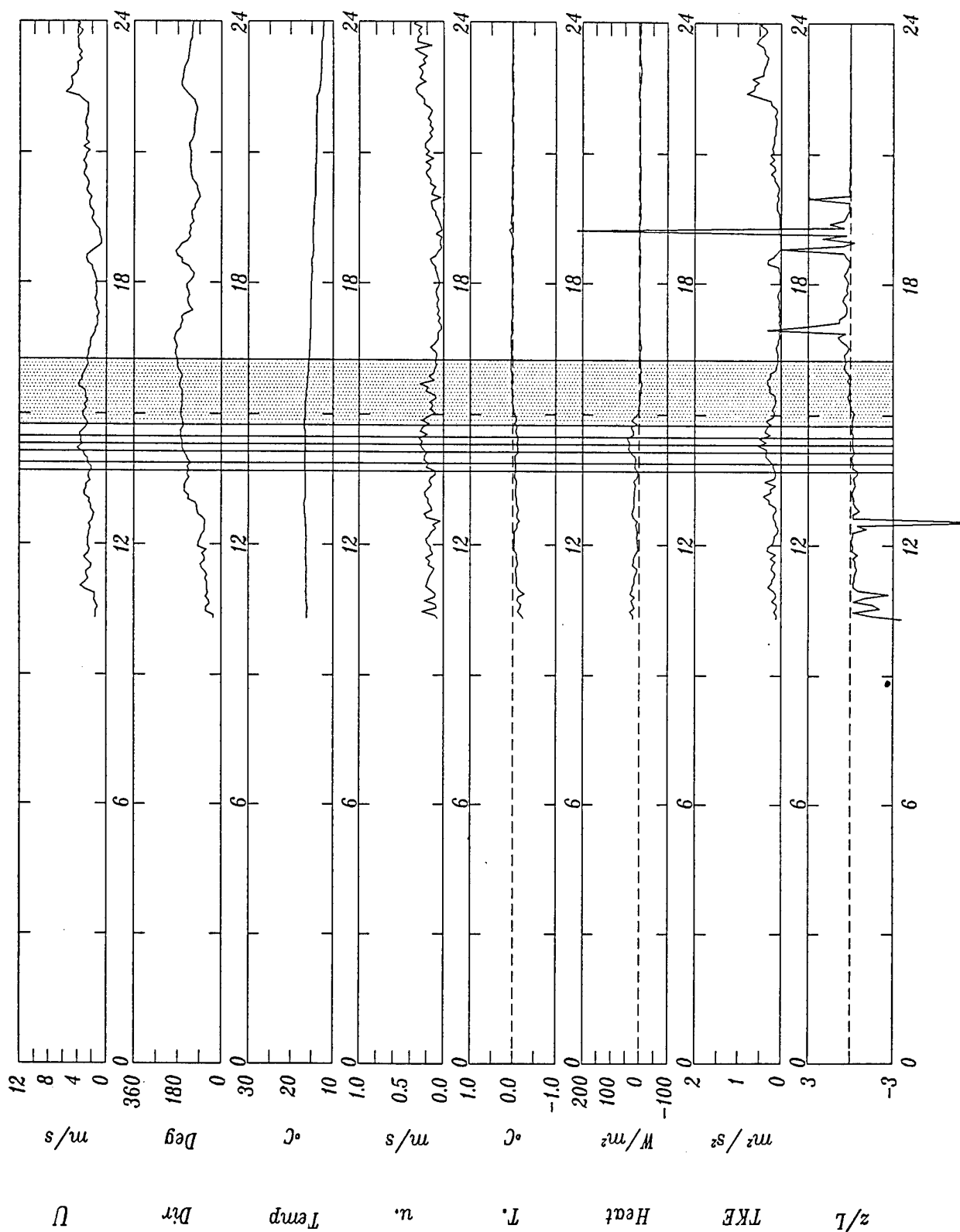
# Sonic 1 micromet: 920921 MADONA



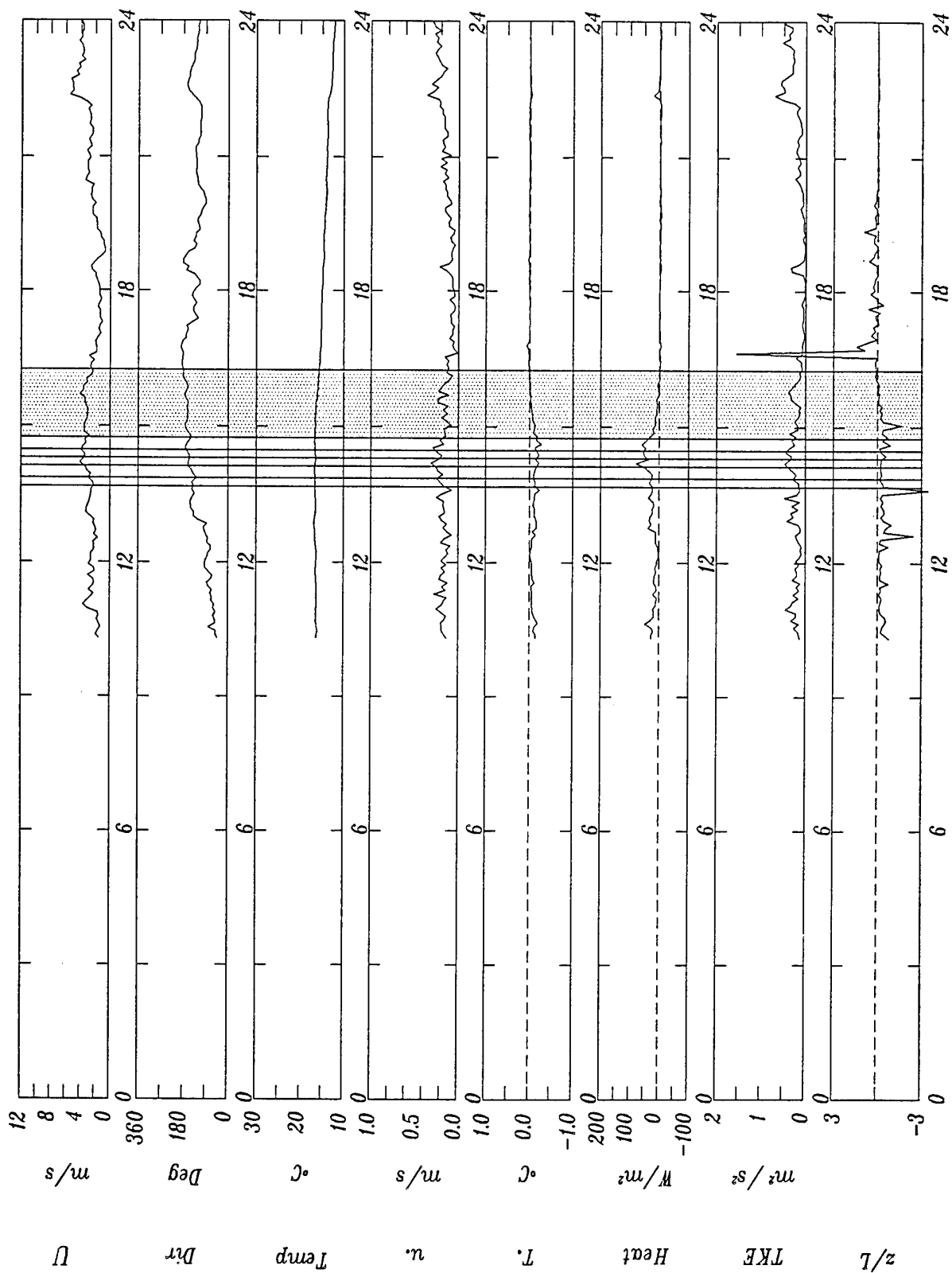
# Sonic 2 micromet: 920921 MADONA



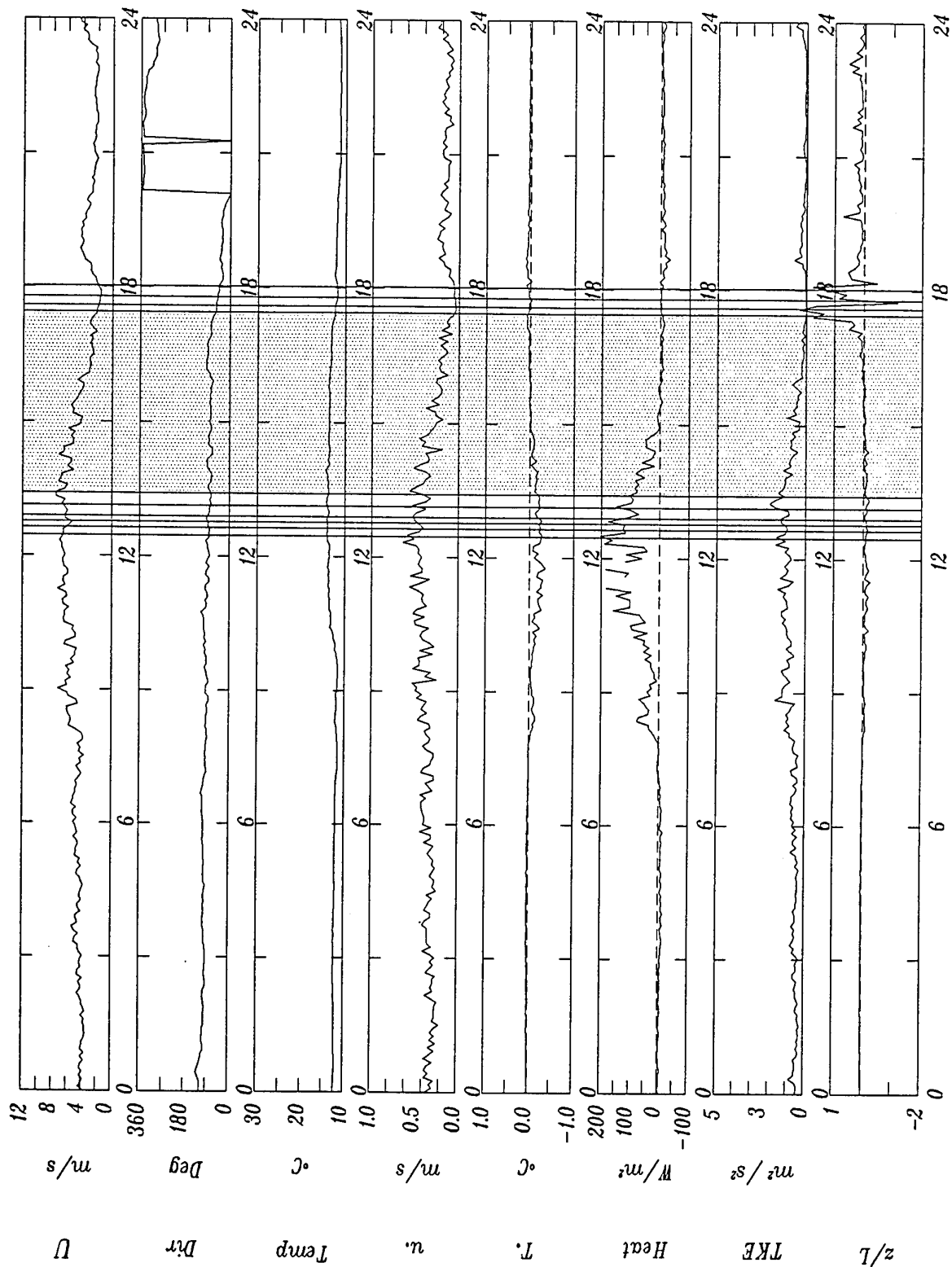
Sonic 1 micromet: 920922 MADONA



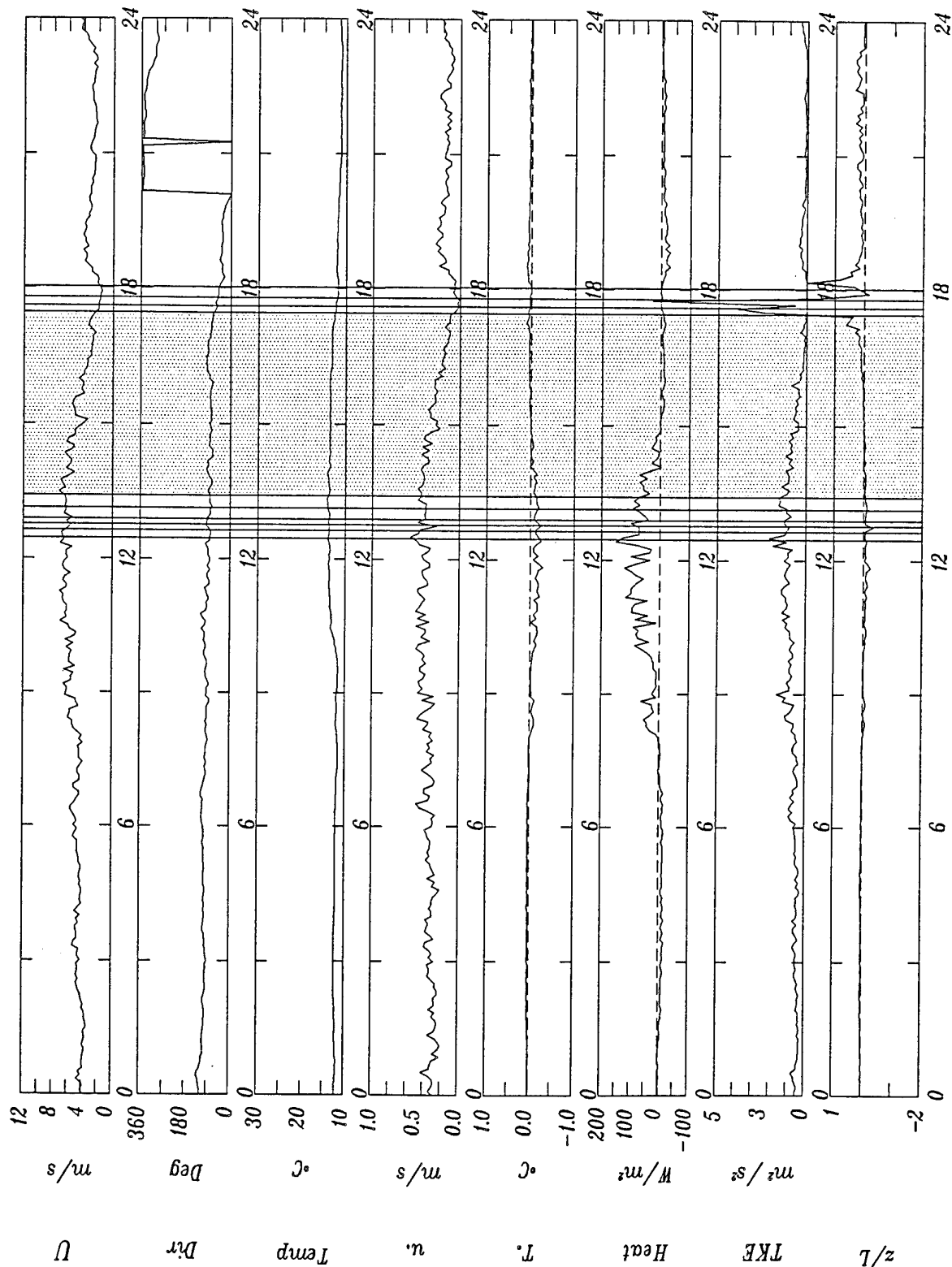
# Sonic 2 micromet: 920922 MADONA



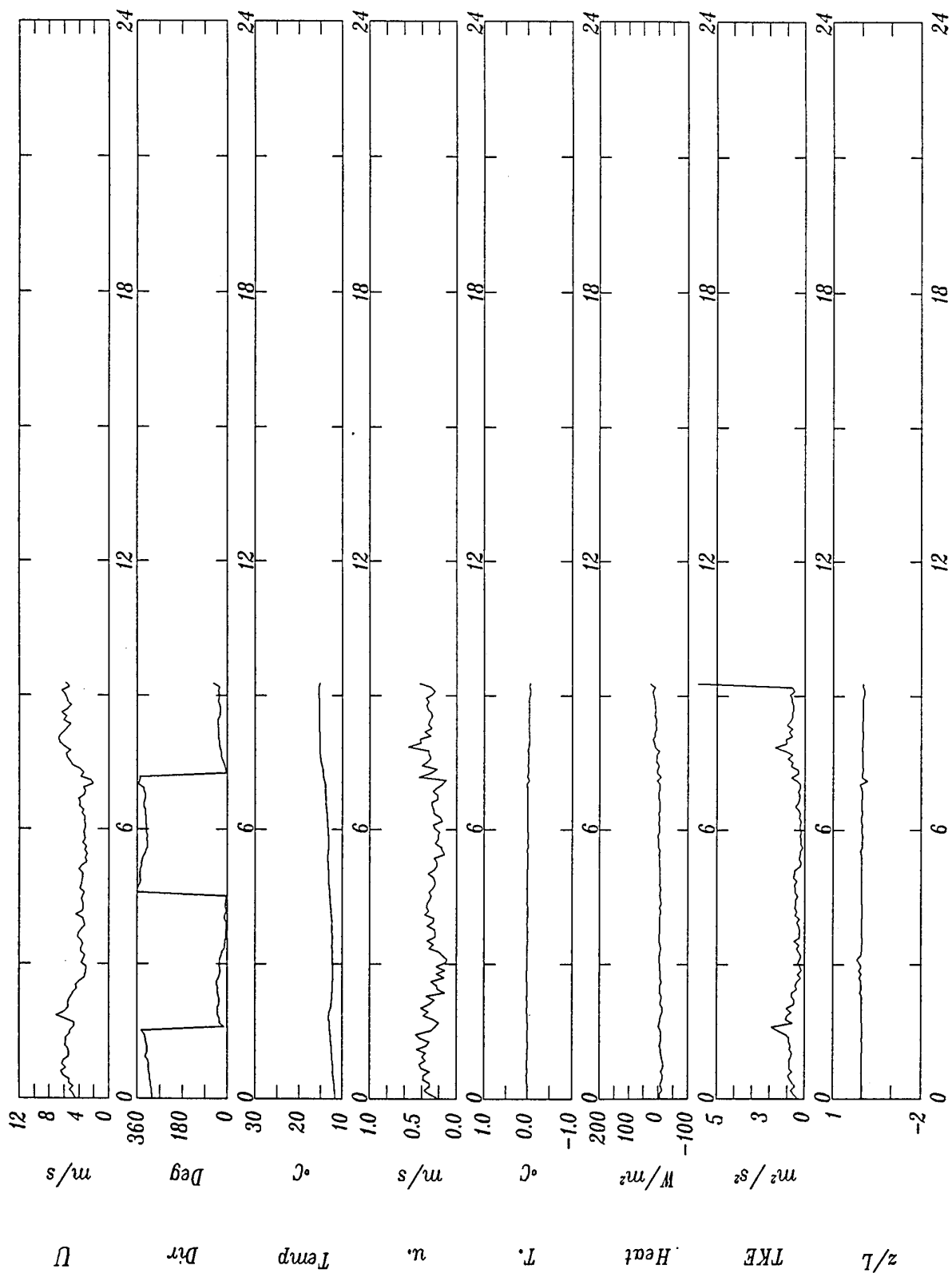
# Sonic 1 micromet: 920923 MADONA



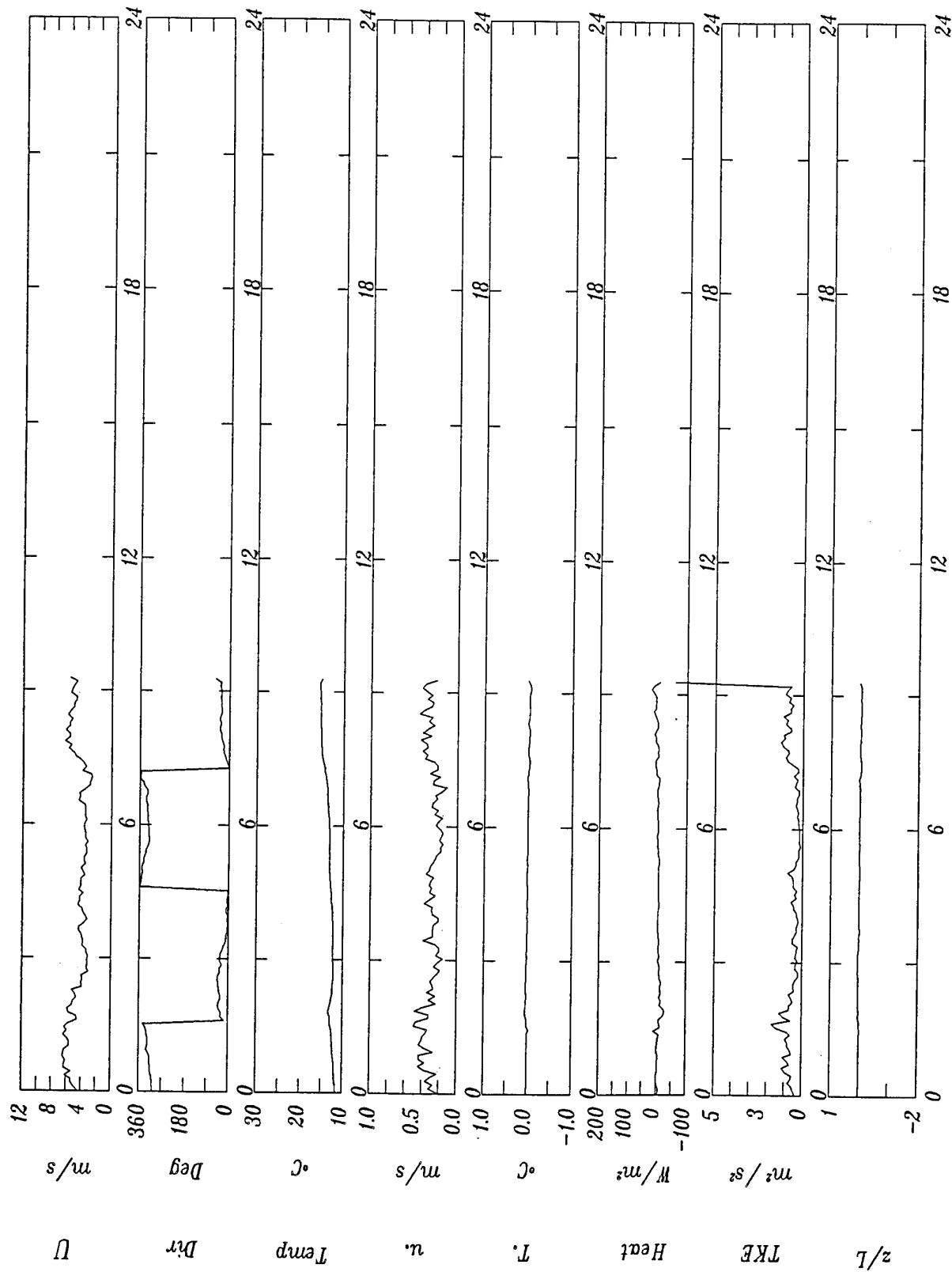
# Sonic 2 micromet: 920923 MADONA



# Sonic 1 micromet: 920924 MADONA

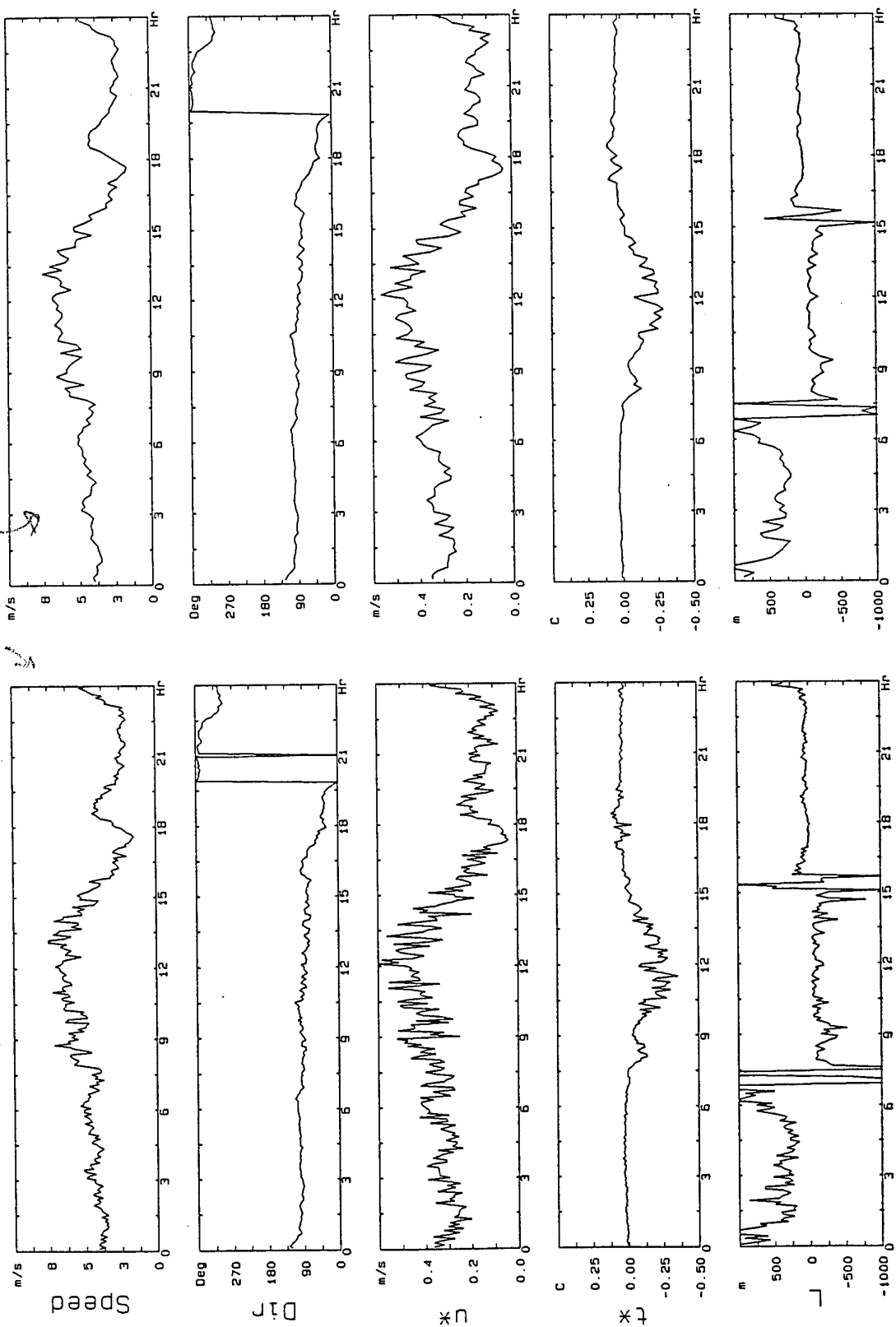


Sonic 2 micromet: 920924 MADONA

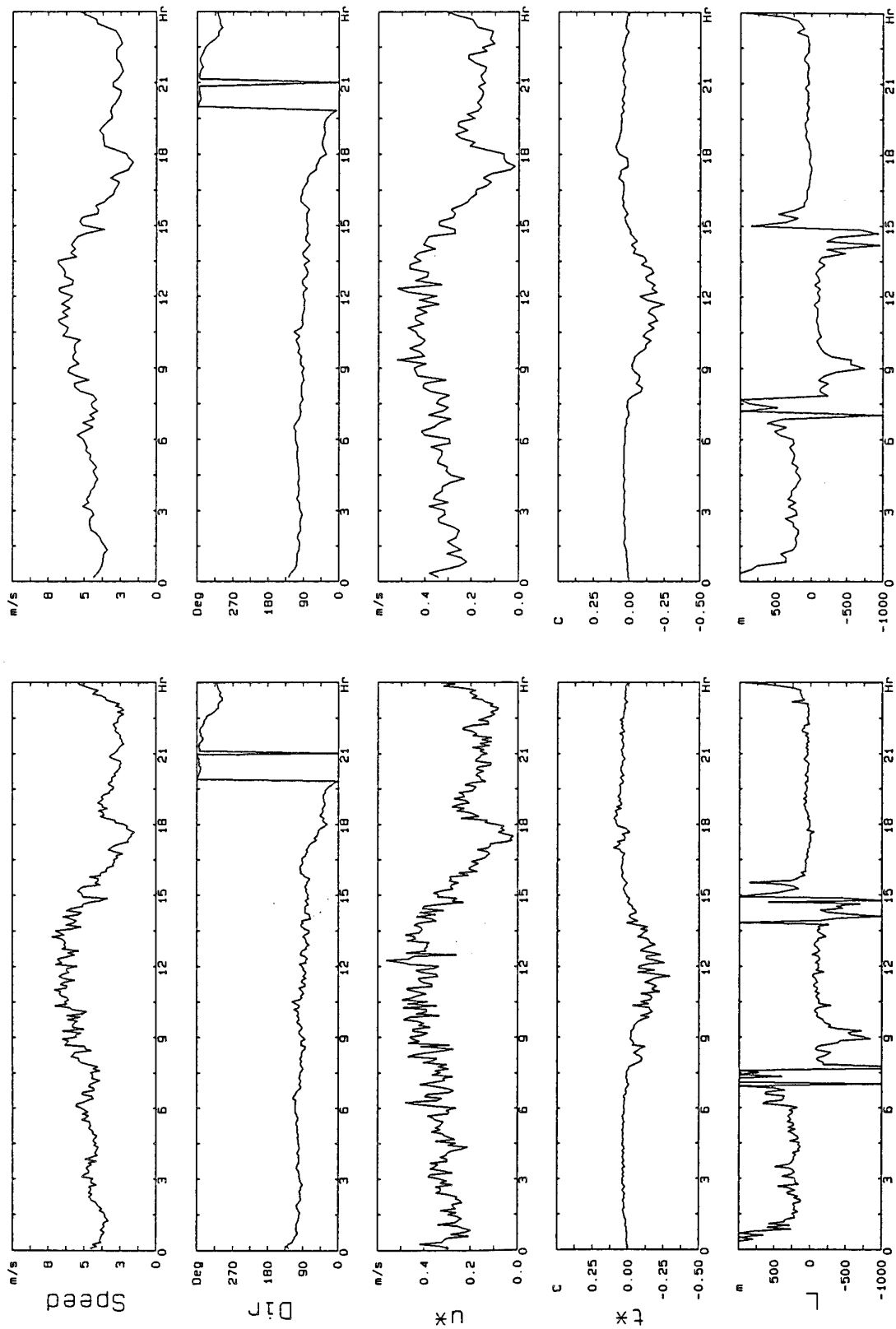


# Appendix II.2

Porton, 23/9 comparison of 5 and 10 min stats. Sonic 1



Porton, 23/9 comparison of 5 and 10 min stats, Sonic 2



Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3°	S14-1	L14-1
mad14b	-	---	13:52:00	-	-	--	--
mad14c	-	---	14:00:15	-	-	--	--
mad14d	+	---	14:08:?	-	-	--	--
mad14e	+	---	14:18:15	-	-	--	--
mad14f	-	---	14:28:30	-	0°	--	--
mad14g	+	puff	14:54:?	2.3	-	S14-2	--
mad14h	+	cont	15:29-16:11	1.0	-	S14-3	L14-3
mad14i	+	----	16:14-16:33	-	-	--	--
mad14j	+	----	16:35-16:43	-	-	--	--
mad14k	+	----	16:47-17:43	-	-	--	--
mad15a	+	puff	13:29:00	2.9	-	S15-1	L15-1
mad15b	+	---	13:38:50	-	-	--	--
mad15c	+	---	13:45:17	-	-	--	--
mad15d	+	---	13:53:00	-	-	--	--
mad15e	+	---	14:01:30	-	-	--	--
mad15f	+	---	14:09:00	-	-	--	--
mad15g	+	---	14:15:30	-	-	--	--
mad15h	+	cont	15:00-15:14	1.0	-	--	--
mad15i	+	----	15:16-15:43	-	-	--	--
mad15j	+	----	15:46-16:10	-	-	--	--
mad15k	+	----	16:13-16:30	-	-	--	--
mad15l	+	----	16:33-16:39	-	-	--	--
mad15m	+	puff	17:19:00	2.9	-	--	--
mad15n	+	---	17:48:10	-	-	--	--

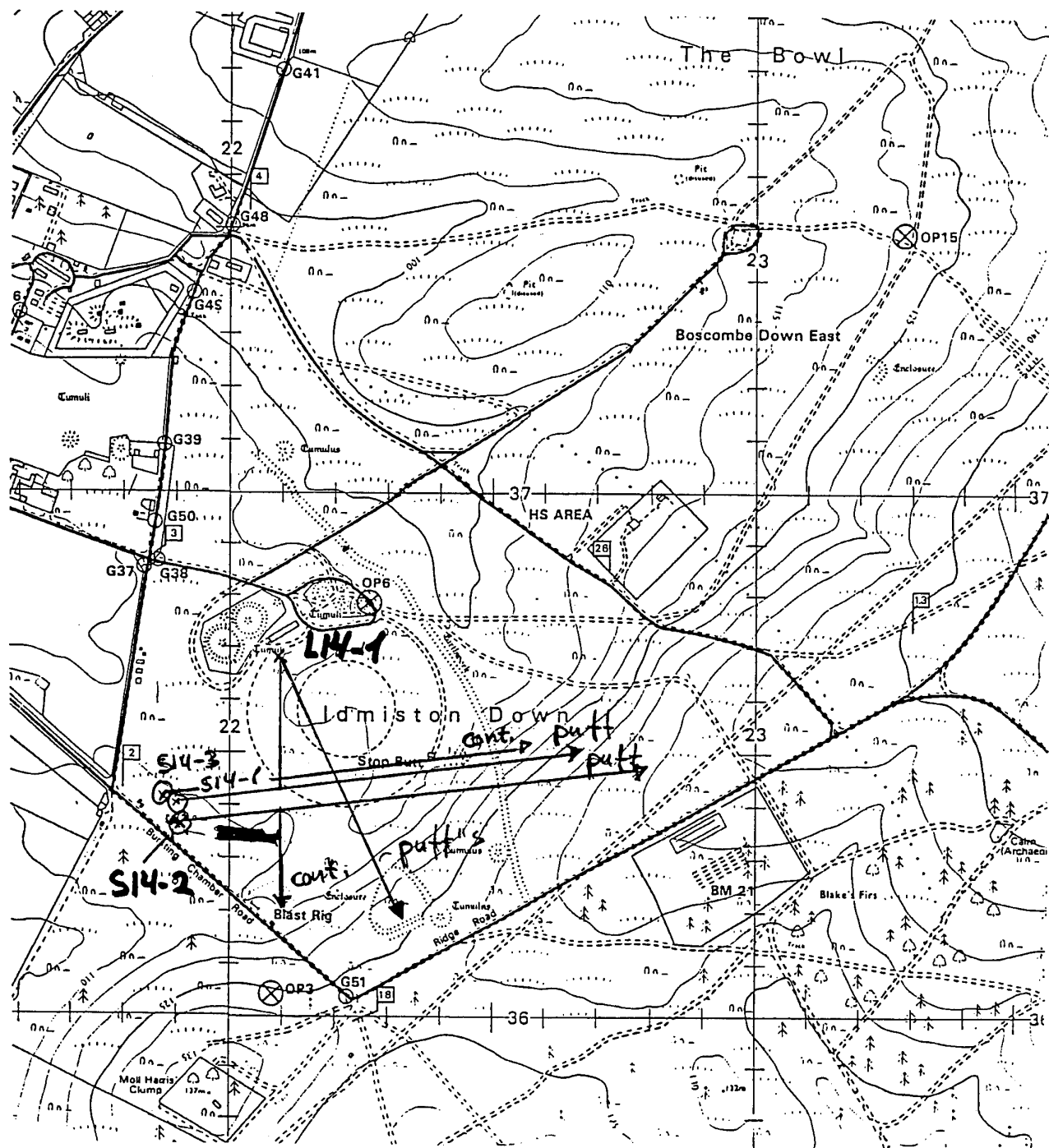
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3°	S14-1	L14-1
mad16a	+	puff	14:04:00	1.0	-8m oT.	S16-1	L16-1
mad16b	+	---	14:34:45	-	--	--	--
mad16c	-	---	14:51:20	-	--	--	--
mad16d	+	---	15:02:10	-	--	--	--
mad16e	-	---	16:00:00	-	--	--	--
mad16f	+	---	?16:15:30	-	--	--	--
mad16g	+	---	16:26:00	-	--	--	--
mad16h	+	---	16:39:15	-	--	--	--
mad16i	+	---	16:52:15	-	--	--	--
mad16j	+	---	17:04:30	-	--	--	--
mad16k	+	---	17:18:00	-	--	--	--
mad16l	+	---	17:30:00	-	--	--	--
mad16m	+	---	17:48:45	-	--	--	--
mad16n	+	---	18:12:50	-	--	--	--
mad16o	+	---	18:42:32	-	--	--	--
mad18a	+	cont	17:56-18:37	1.0	1-2°	S18-1	L18-1
mad19a	+	puff	13:15:00	6.0	2-3°	S19-1	L19-1A
mad19b	+	---	?13:25:00	-	--	--	--
mad19c	+	---	13:36:00	-	--	--	--
mad19d	-	---	13:47:23	-	--	--	--
mad19e	+	cont	15:09-15:52	1.0	3°	S19-1	L19-1
mad19f	-	puff	16:10:40	6.0	--	--	L19-2
mad19g	+	---	16:26:35	-	--	--	--
mad19h	+	---	17:49:30	-	5m oT	S19-3	L19-2

Name	Qua	Type of relase	Time (HMs)	Release heighth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3°	S14-1	L14-1
mad19i	+	---	18:01:00	-	--	--	--
mad19j	+	---	18:14:30	-	--	--	--
mad19k	+	---	18:23:00	-	--	--	--
mad19l	+	---	18:30:00	-	--	--	--
mad20a	-	cont	12:07-12:29	1.0	2m oT	S20-1	L20-1
mad20b	(-)	---	12:47-13.01	-	--	--	--
mad20c	+	puff	14:55:22	6.0	2m oT	S20-2	L20-2
mad20d	-	---	15:13:30	-	--	--	--
mad20e	-	---	15:30:00	-	--	--	--
mad20f	-	---				S20-3	L20-3
mad20g	-	---				--	--
mad20h	-	---				--	--
mad20i	-	---				--	--
mad20j	+	---	18:32:00	1.0	--	--	--
mad20k	+	---	18:41:00	-	--	--	--
mad20l	+	---	18:49:00	-	--	--	--
mad20m	+	---	18:56:00	-	--	--	--
mad20n	+	---	19:04:00	-	--	--	--
mad20o	+	---	19:10:00	-	--	--	--
mad21a	+	puff	13:22:30	1.0	0°	S21-1	L21-1
mad21b	+	---	13:32:40	-	--	--	--
mad21c	+	---	13:41:30	-	--	--	--
mad21d	+	---	13:51:20	-	--	--	--
mad21e	+	---	14:04:30	-	--	--	--

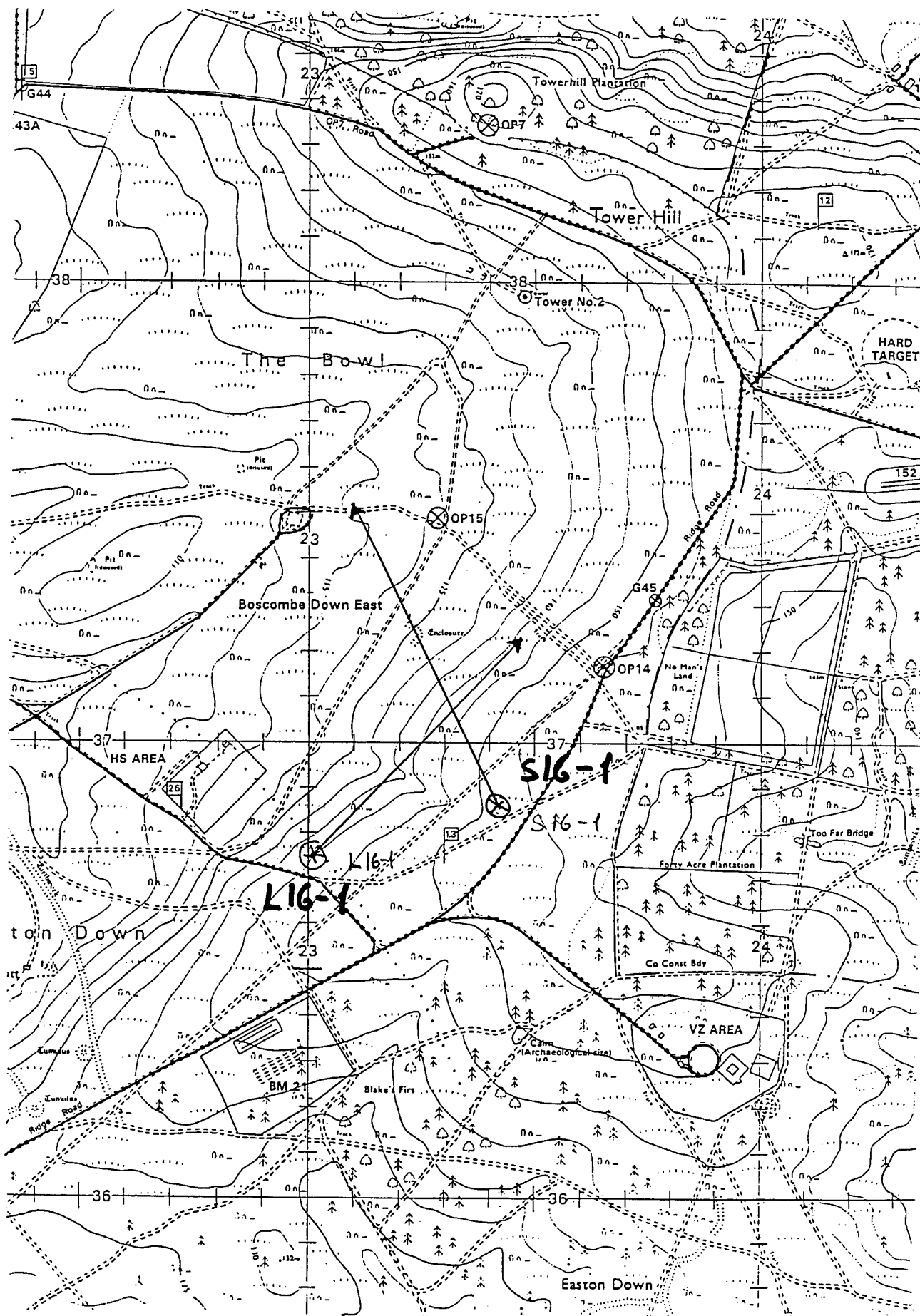
Name	Qua	Type of relase	Time (HMs)	Release heigth (m)	L.s. (m)/deg	Source pos.	Lidar pos
mad14a	+	puff	13:38:30	2.3	3°	S14-1	L14-1
mad21f	(+)	cont	14:42-14:59	1.0	0°	S21-2	L21-2
mad21g	+	cont	15:19-15:43	-	--	--	L21-3
mad21h	(+)	---	15:45-16:17	-	--	--	--
mad21i	(-)	---	16:18-16:40	-	--	--	--
mad21j	-	---	(-)	-	--	--	--
mad21k	++	cont	17:31-18:19	1.0	--	S21-4	L21-4
mad22a	+	puff	13:41:25	2.3	--	S22-1	L22-1
mad22b	+	---	13:52:13	-	--	--	--
mad22c	+	---	14:07:45	-	--	--	--
mad22d	+	---	14:18:35	-	--	--	--
mad22e	+	---	14:29:00	-	--	--	--
mad22f	+	cont	14:51-16:13	1.0	scan	S22-2	--
mad23b	(-)	puff	12:38:30	2.3	2m oT	S23-1	L23-1
mad23c	(+)	---	12:46:30	-	--	--	--
mad23d	(-)	---	12:54:00	-	--	--	--
mad23e	(-)	---	13:08:30	-	--	--	--
mad23f	+	cont	13:32-14:46	1.0	scan	S23-2	--
mad23g	+	---	15:00-17:31	-	--	--	--
mad23h	+	puff	17:36:30	2.3	2m oT	S23-1	--
mad23i	+	---	17:47:30	-	--	--	--

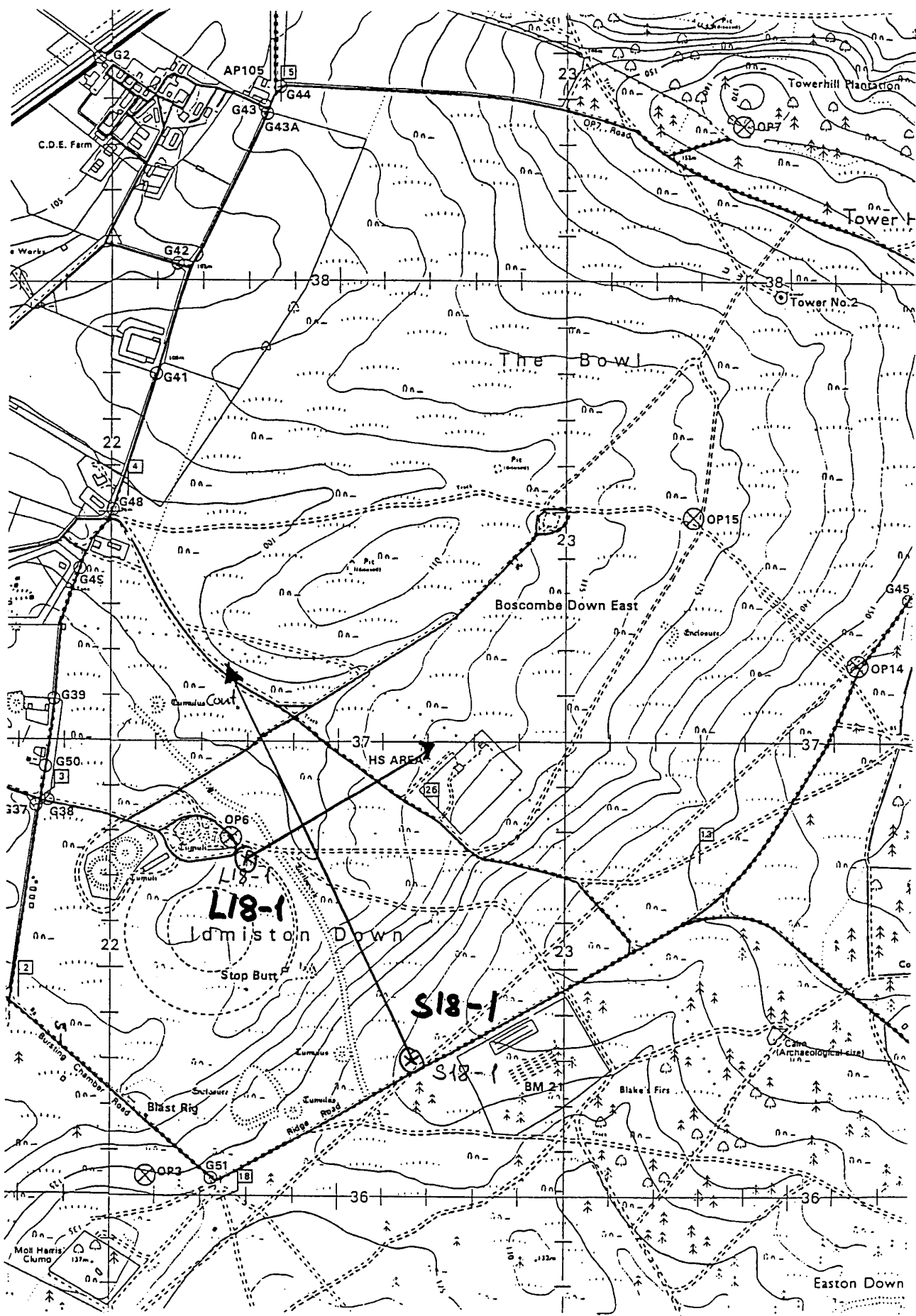
# Appendix III.1

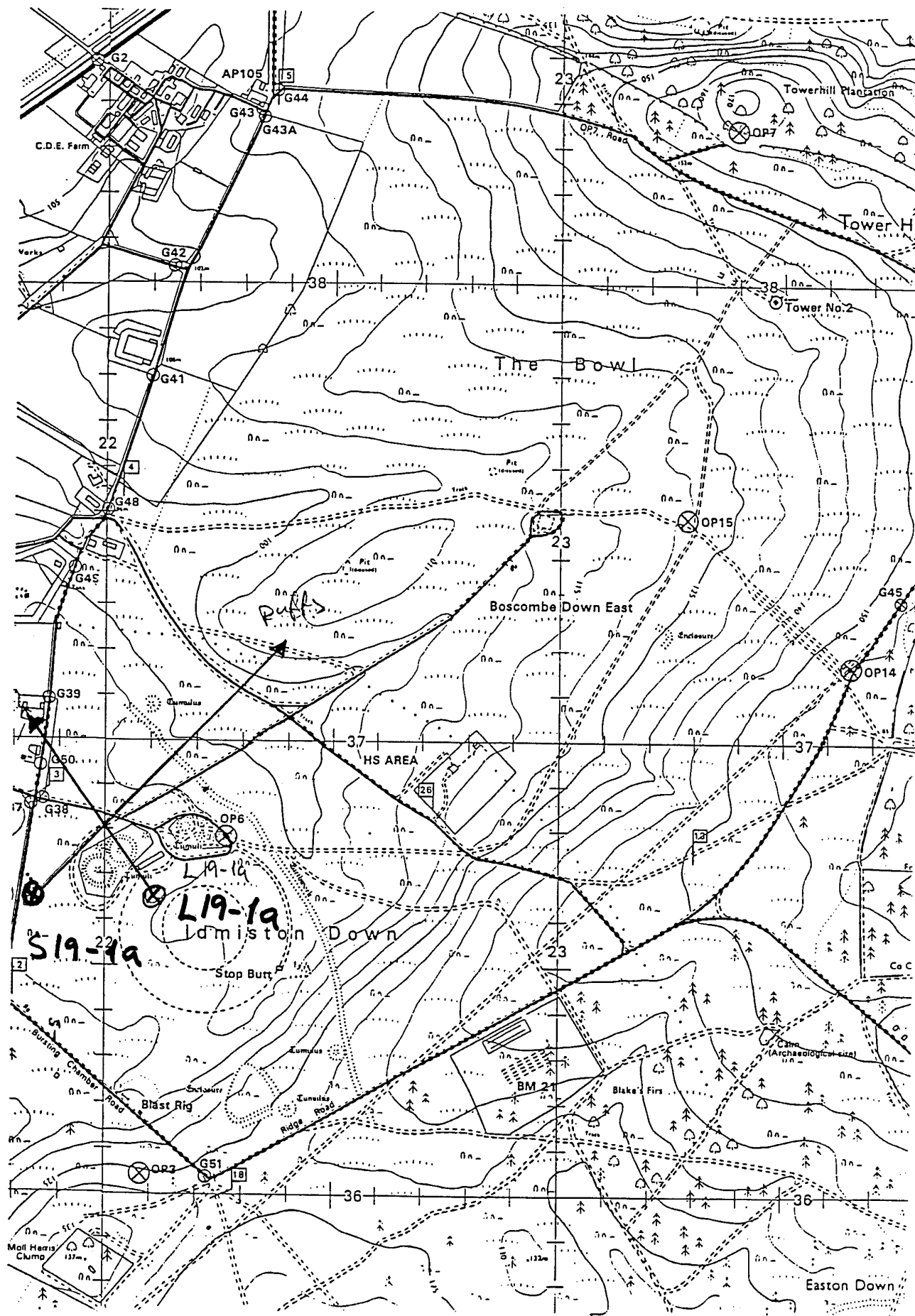
Table III.1b

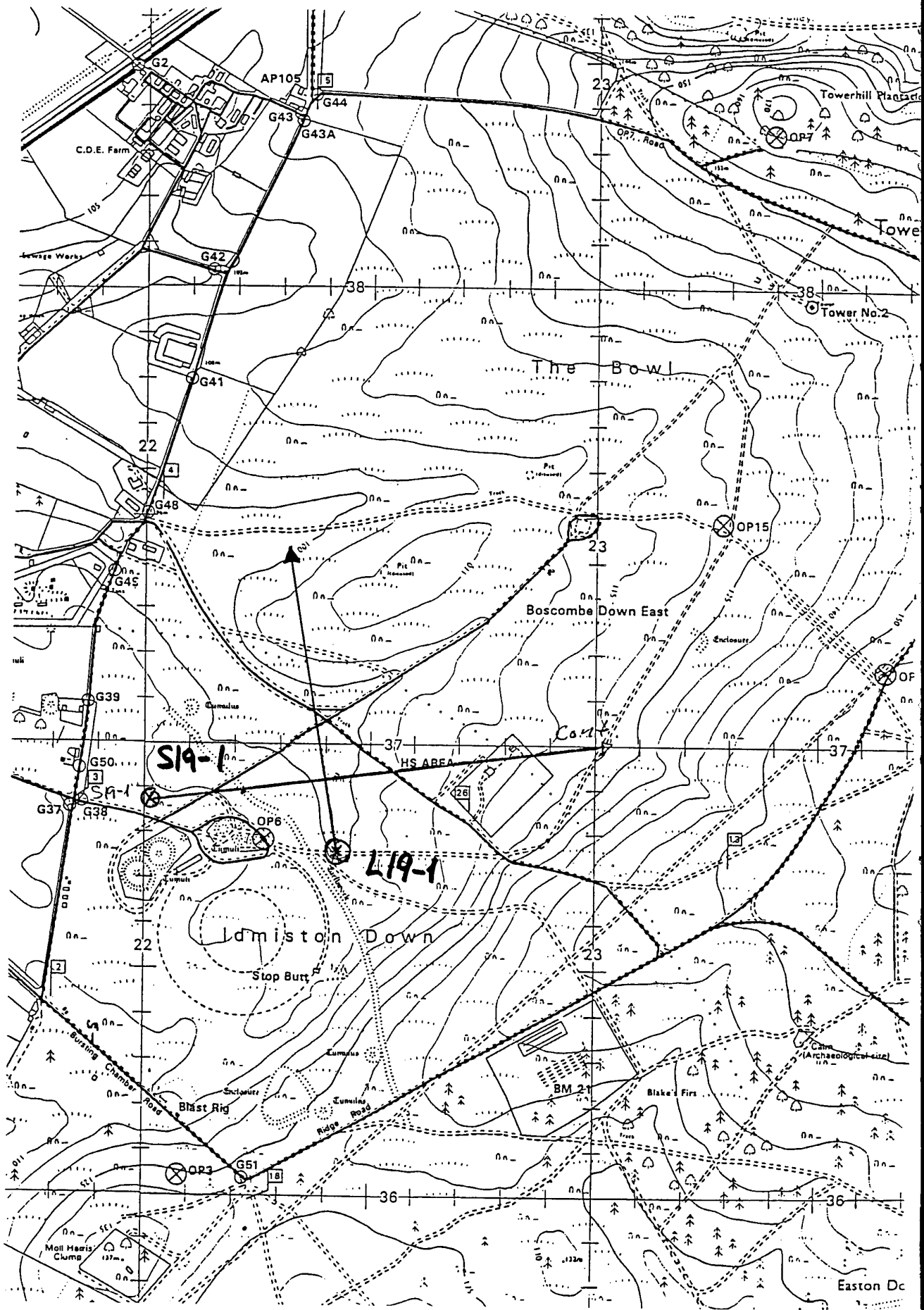


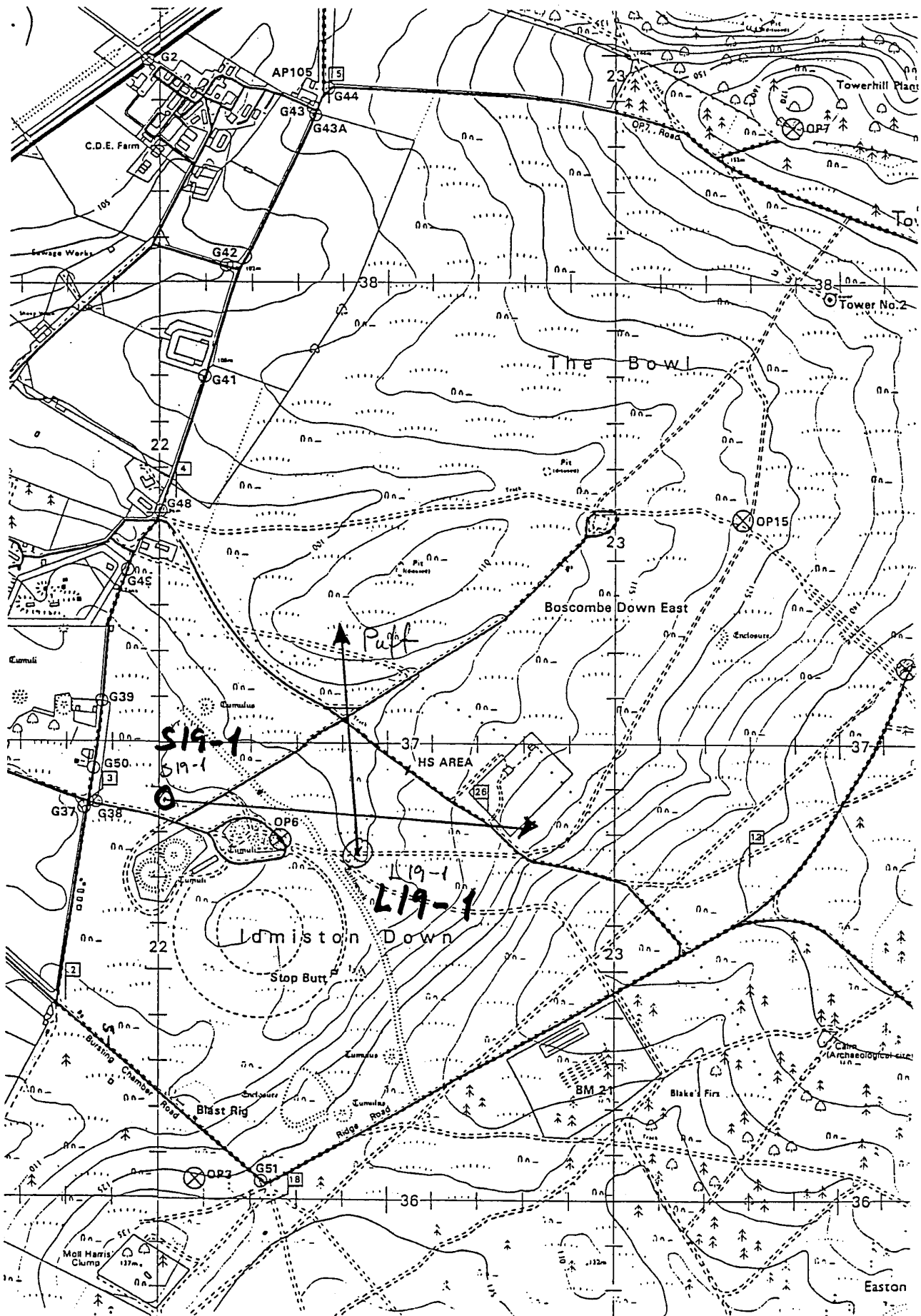


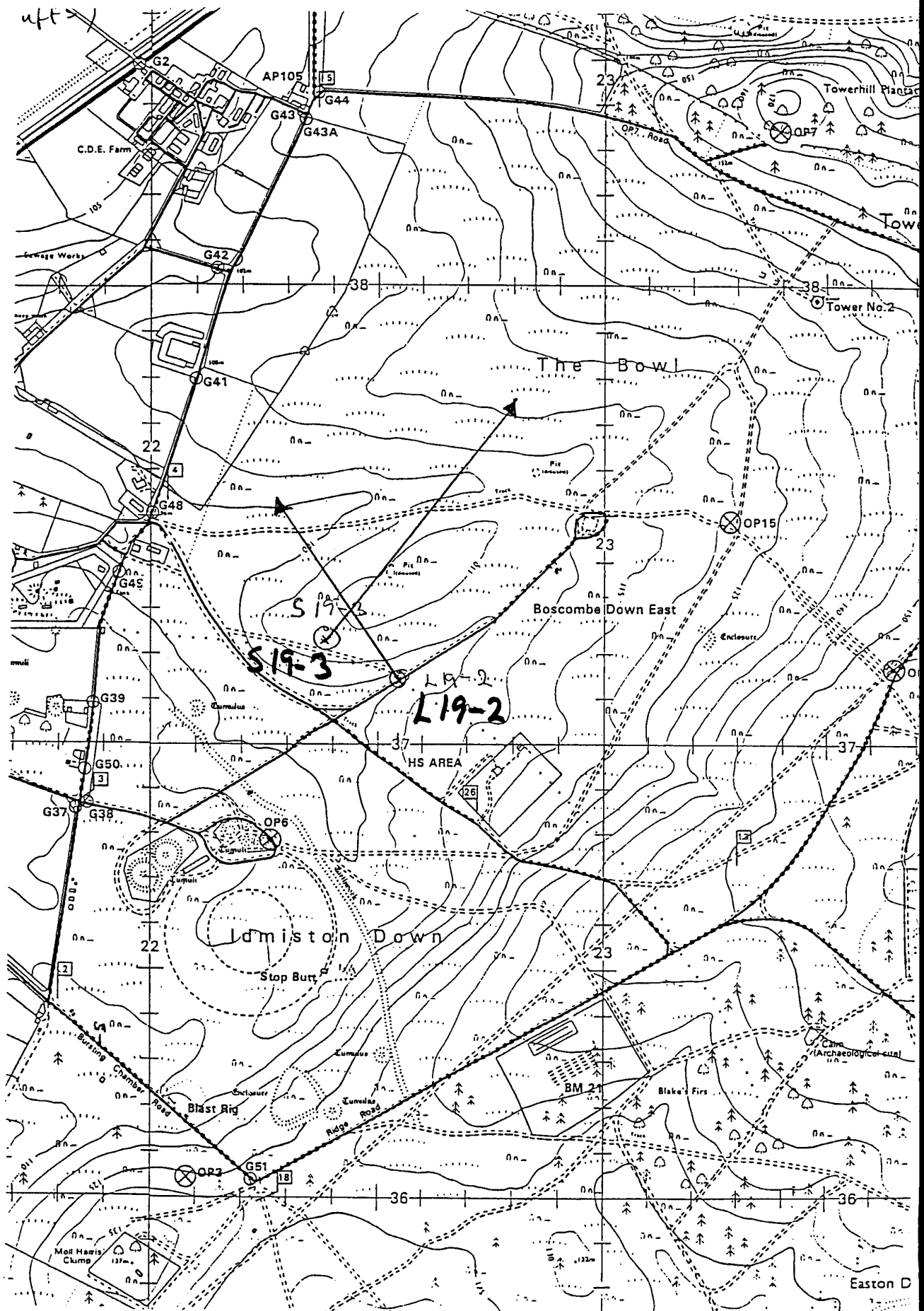


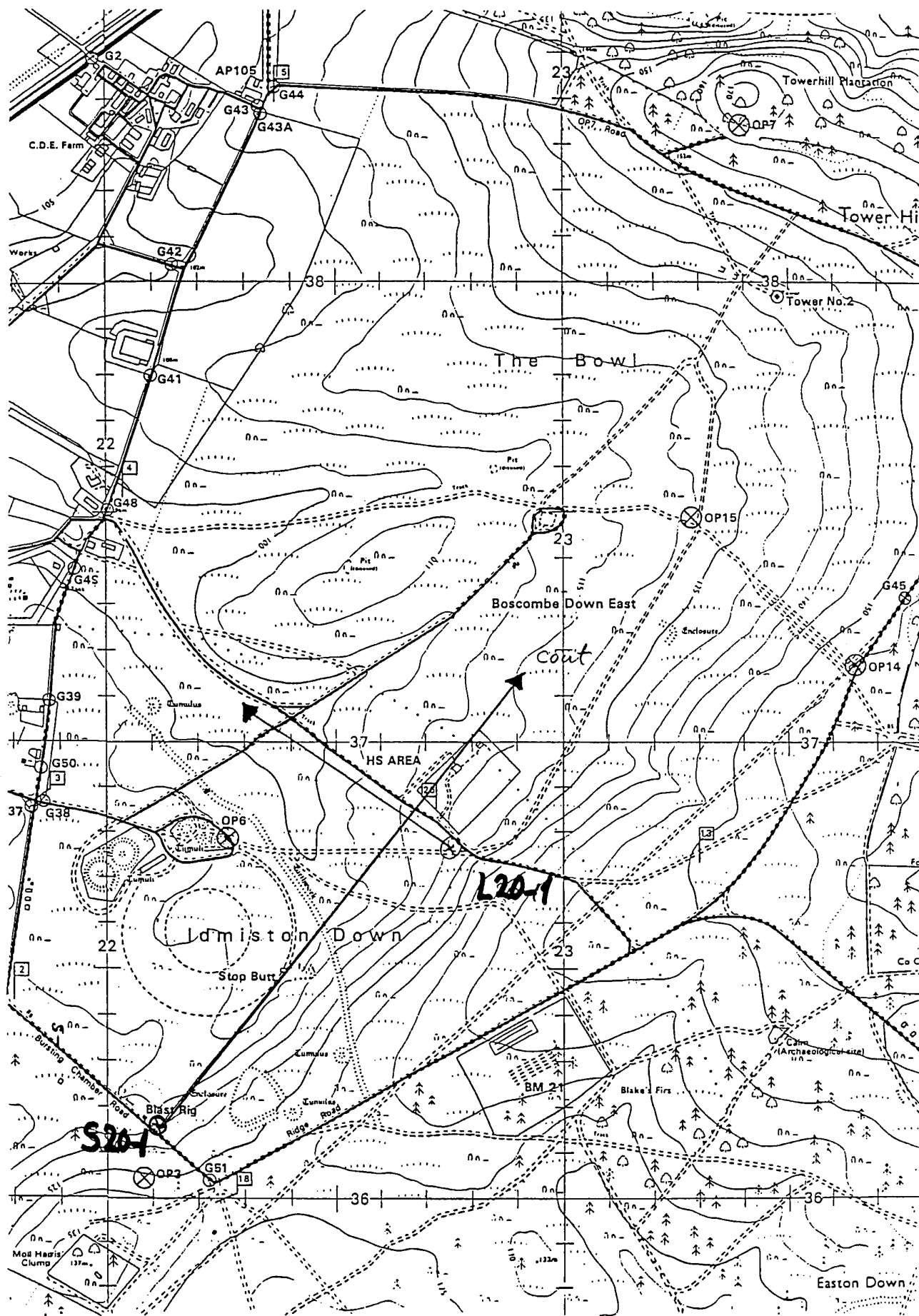




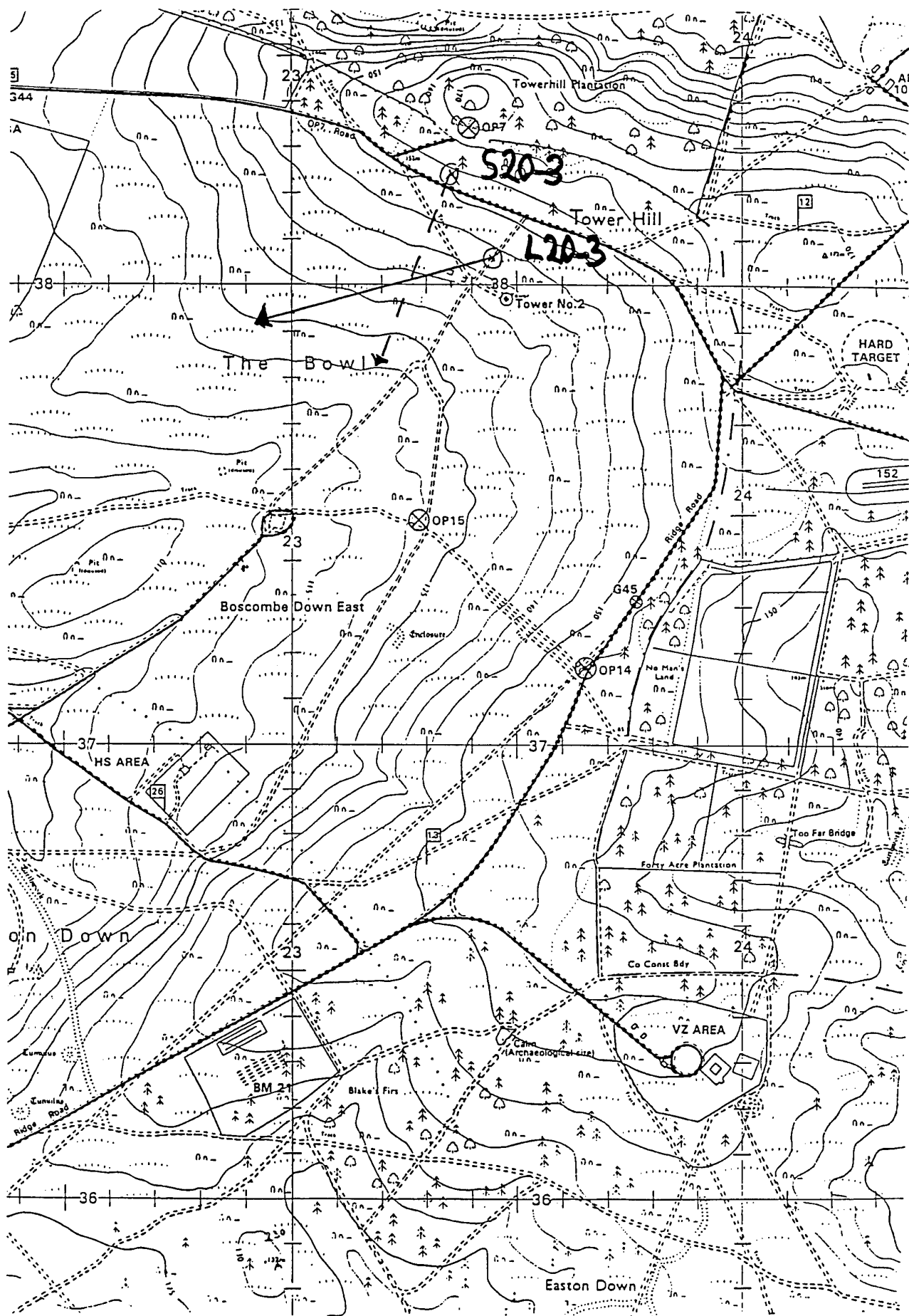


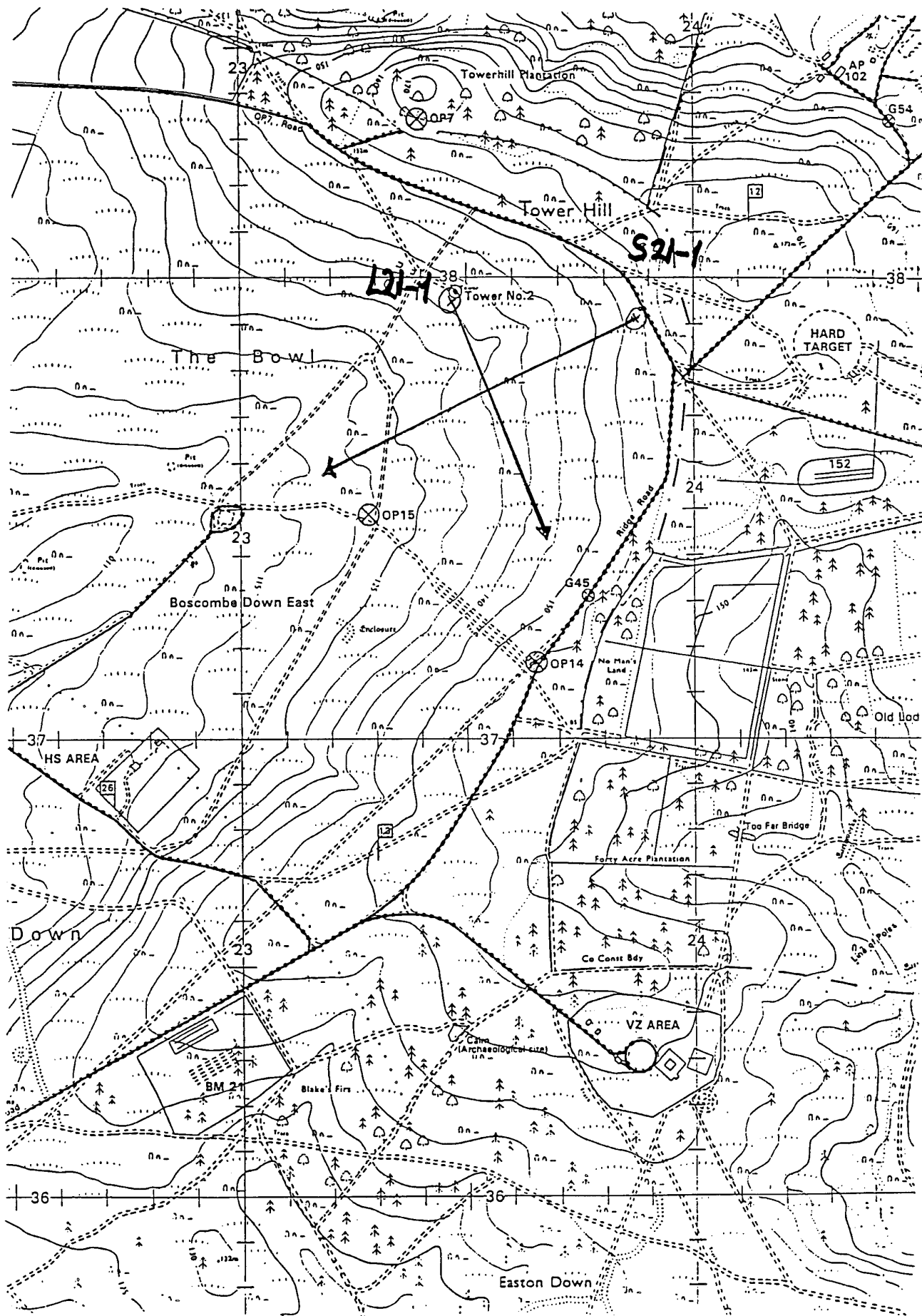




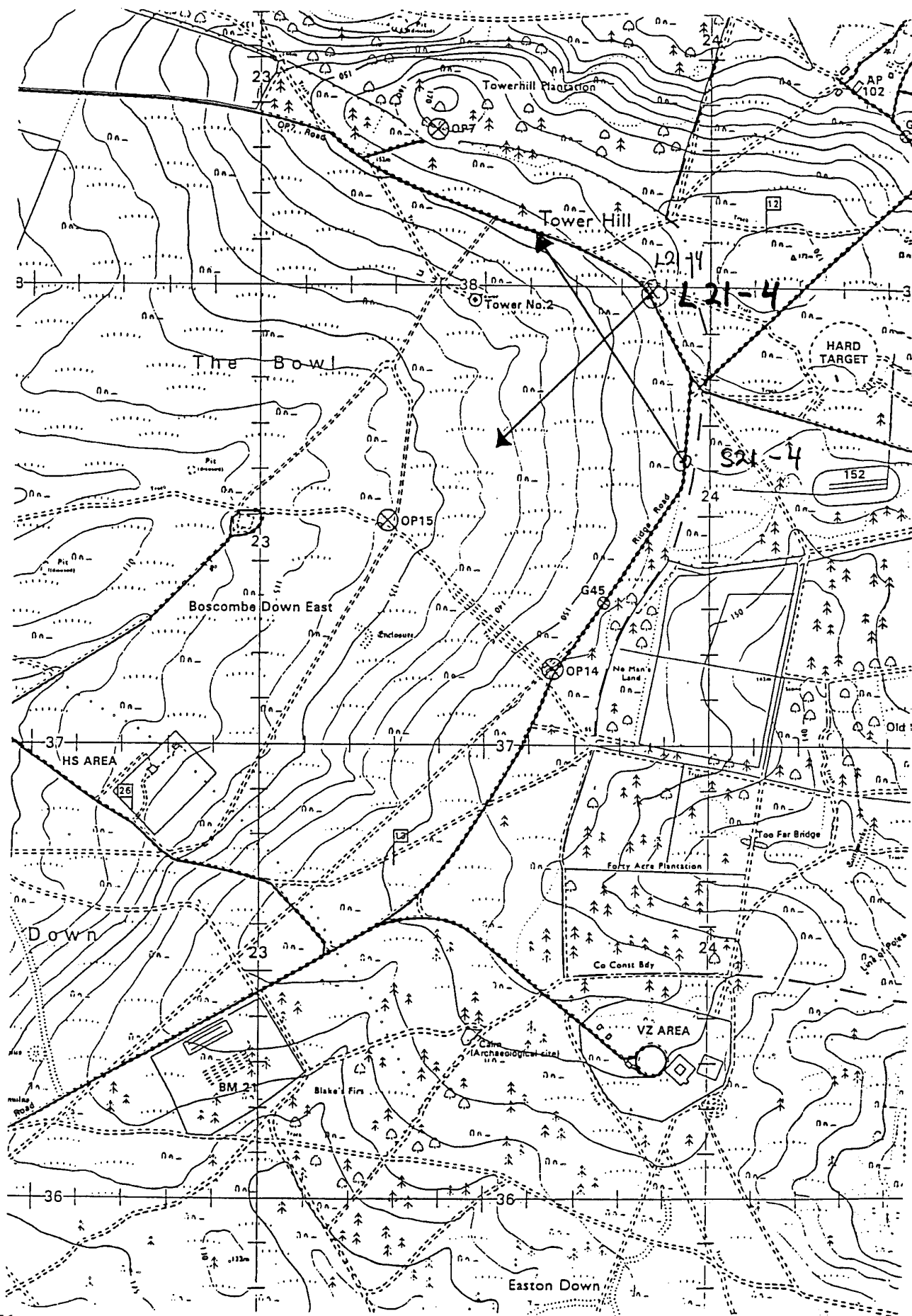


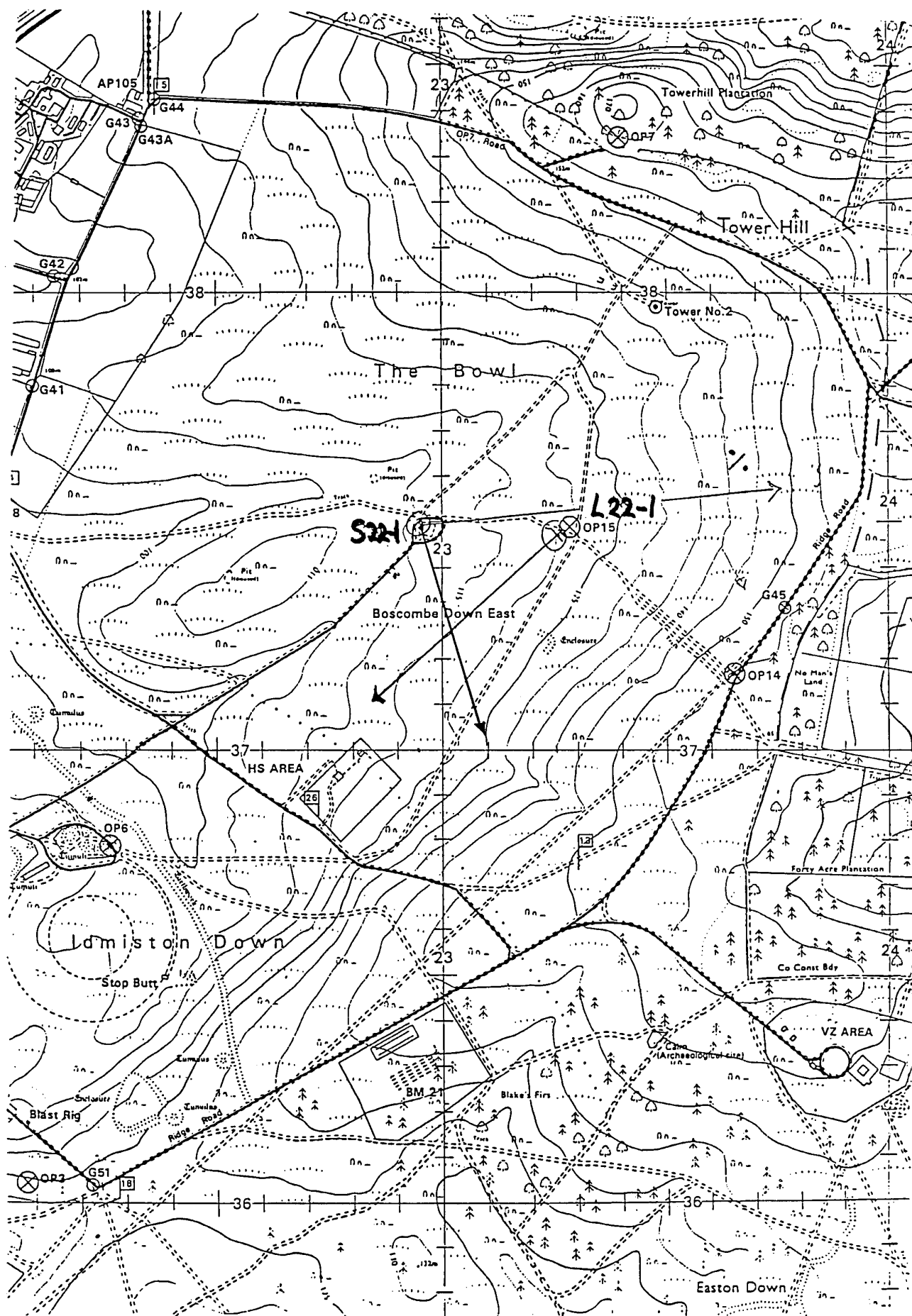


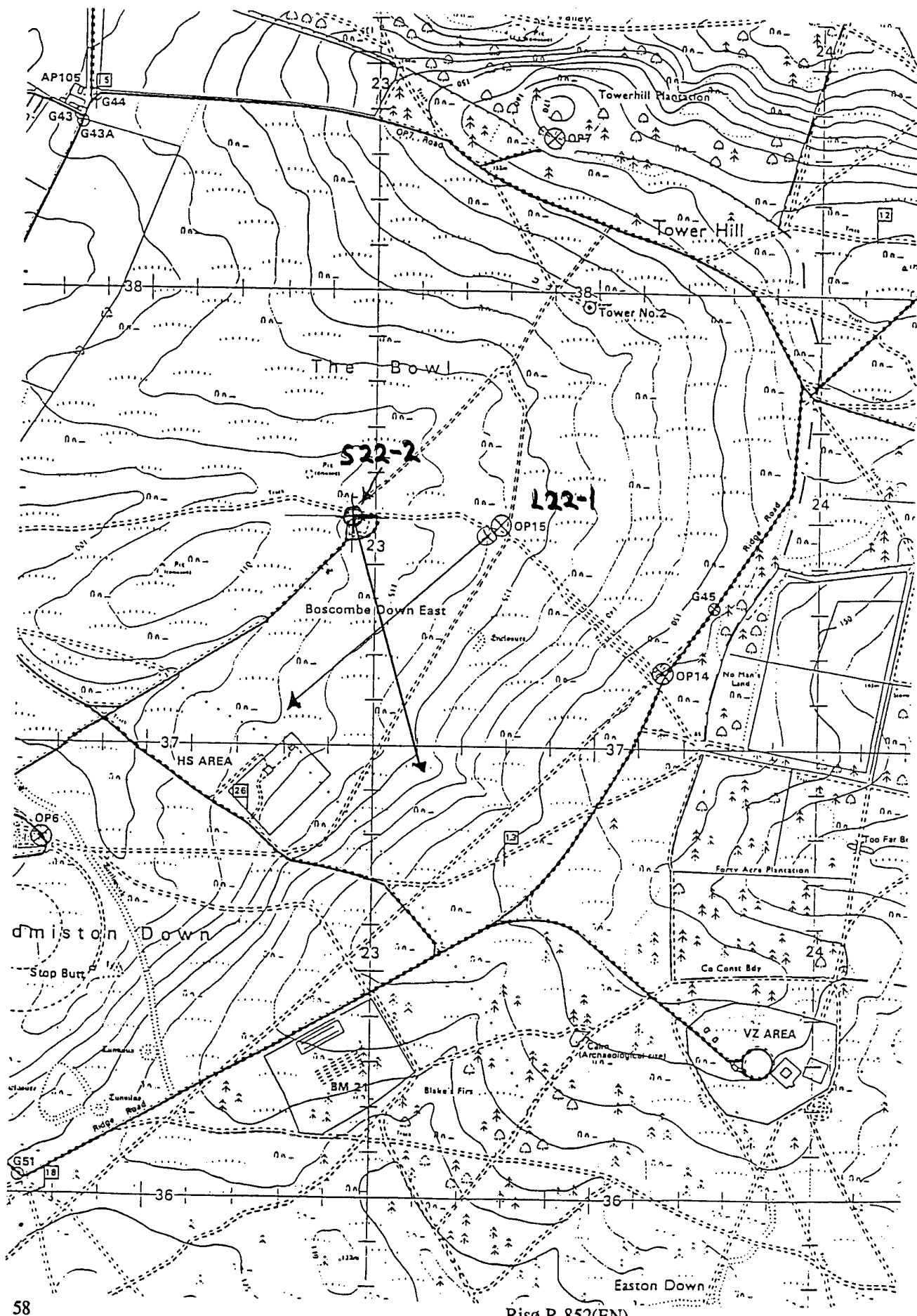














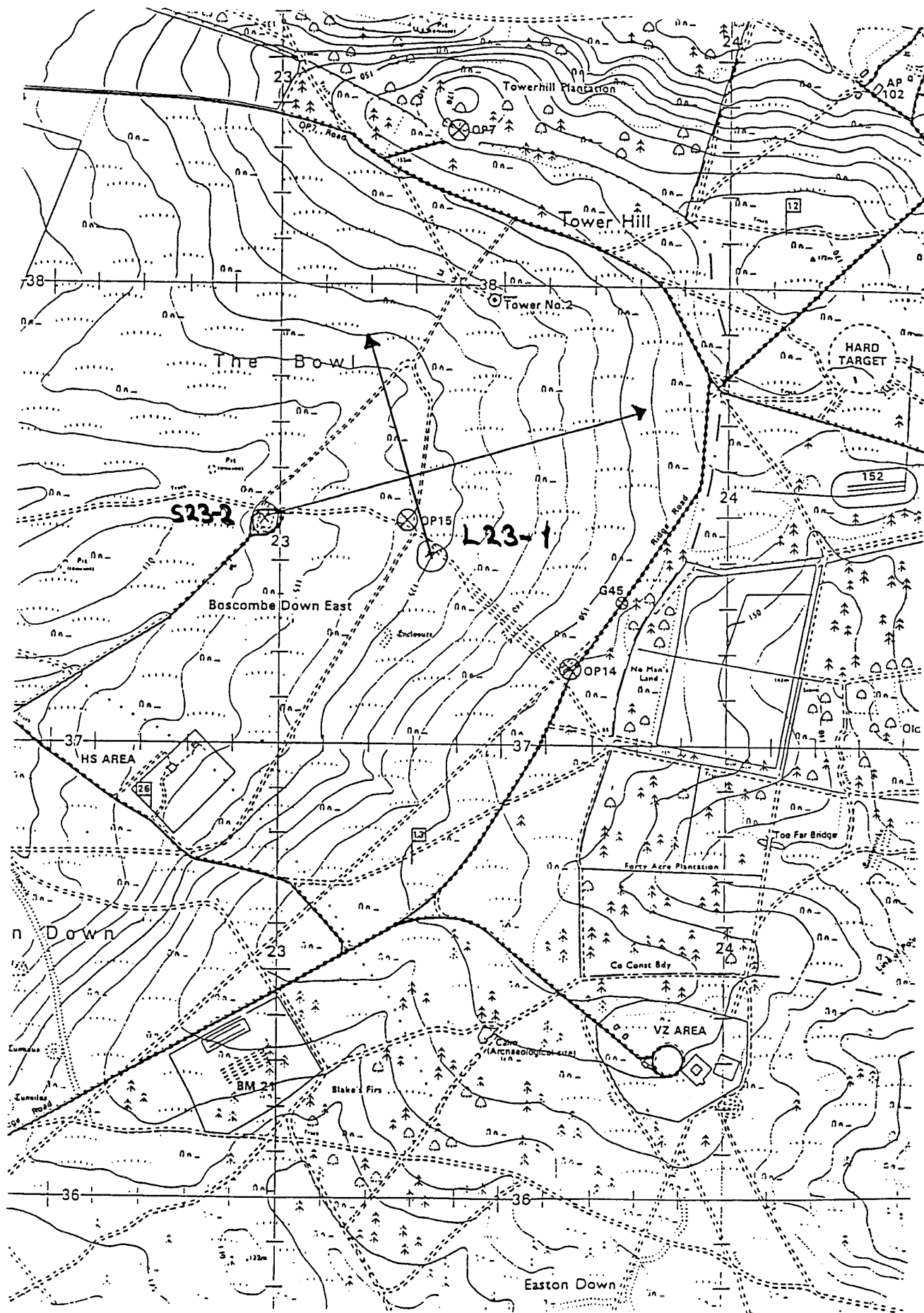
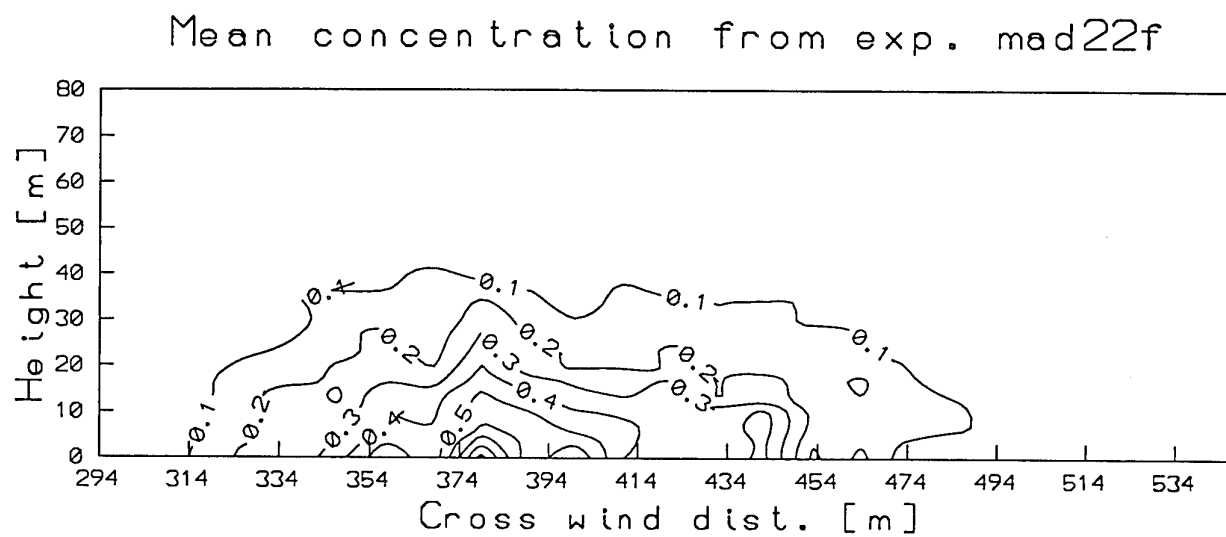


Figure III.1



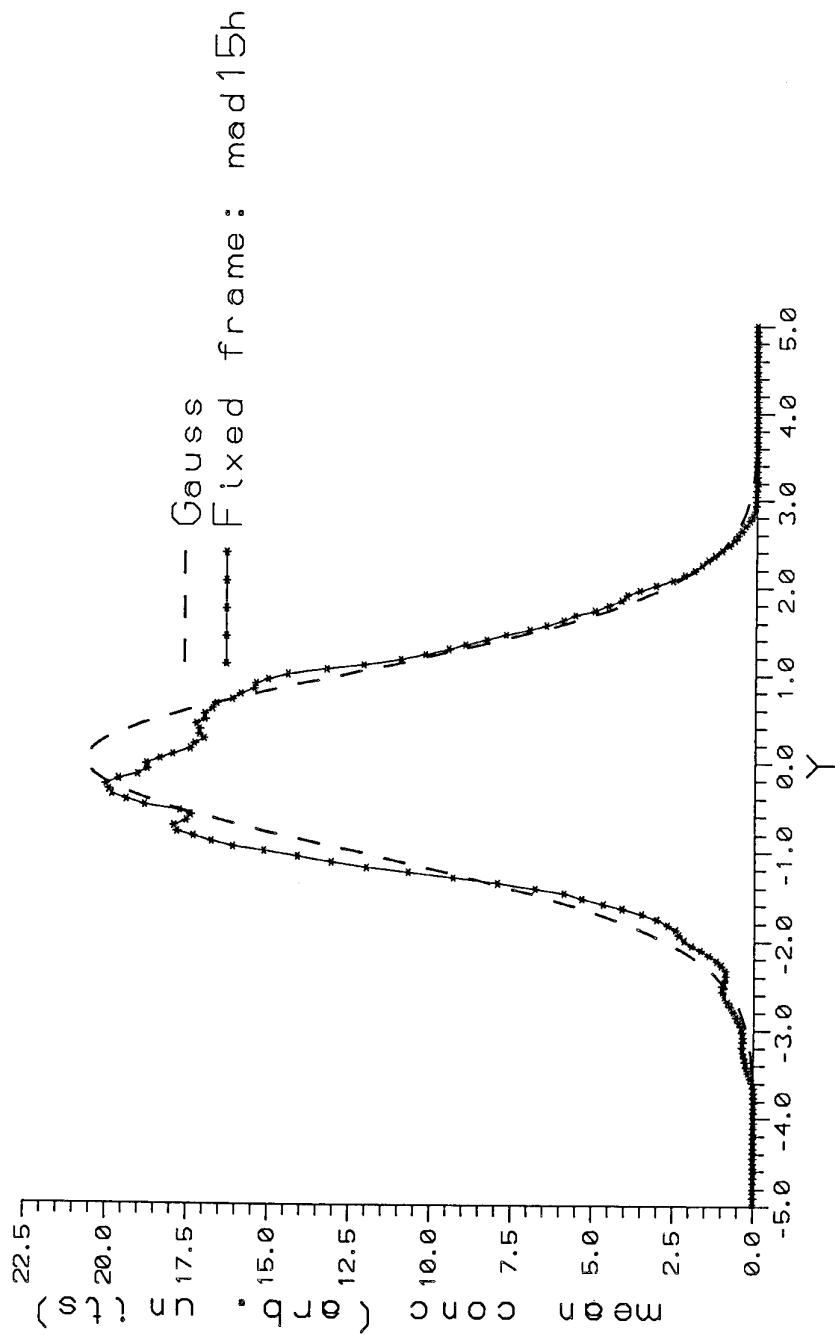


Figure III.2a

Figure III.2b

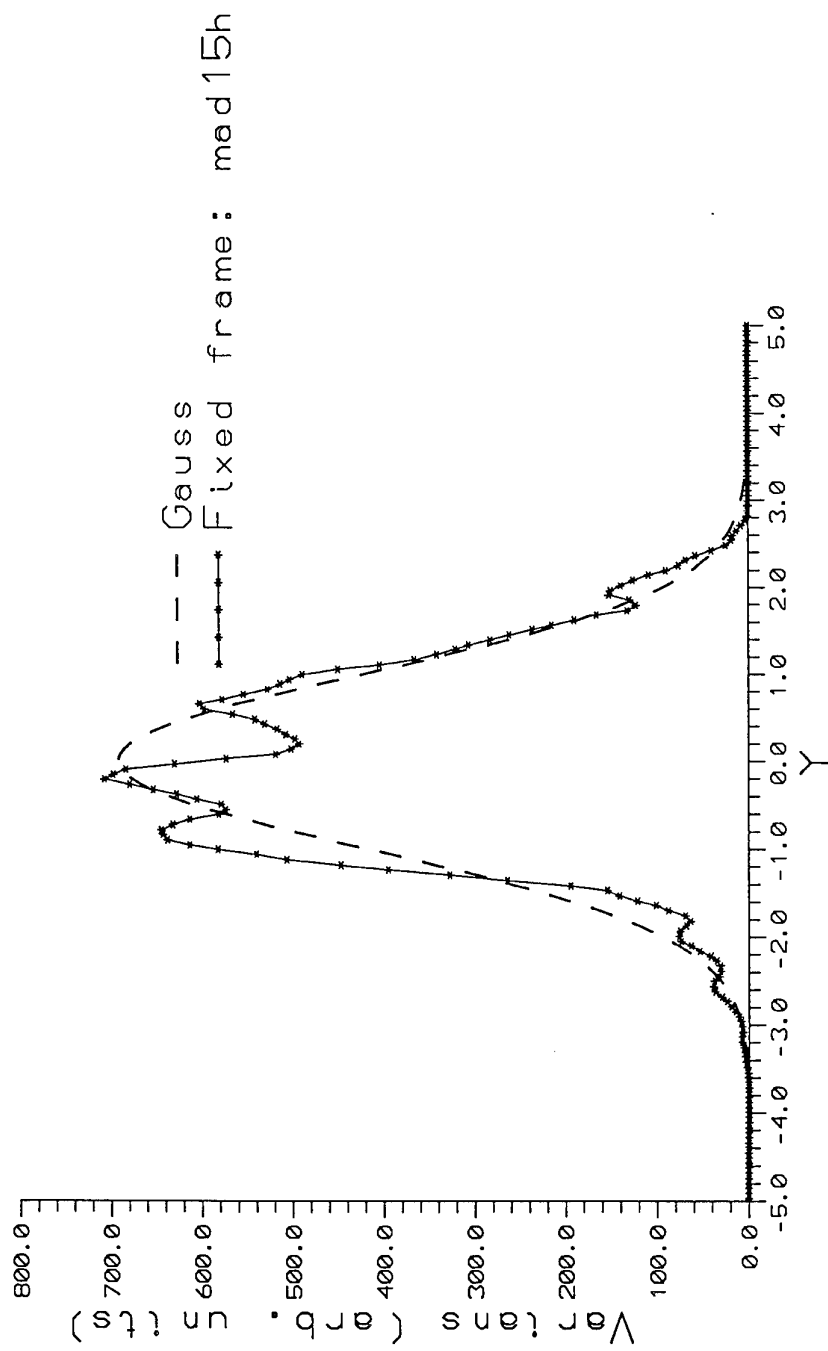
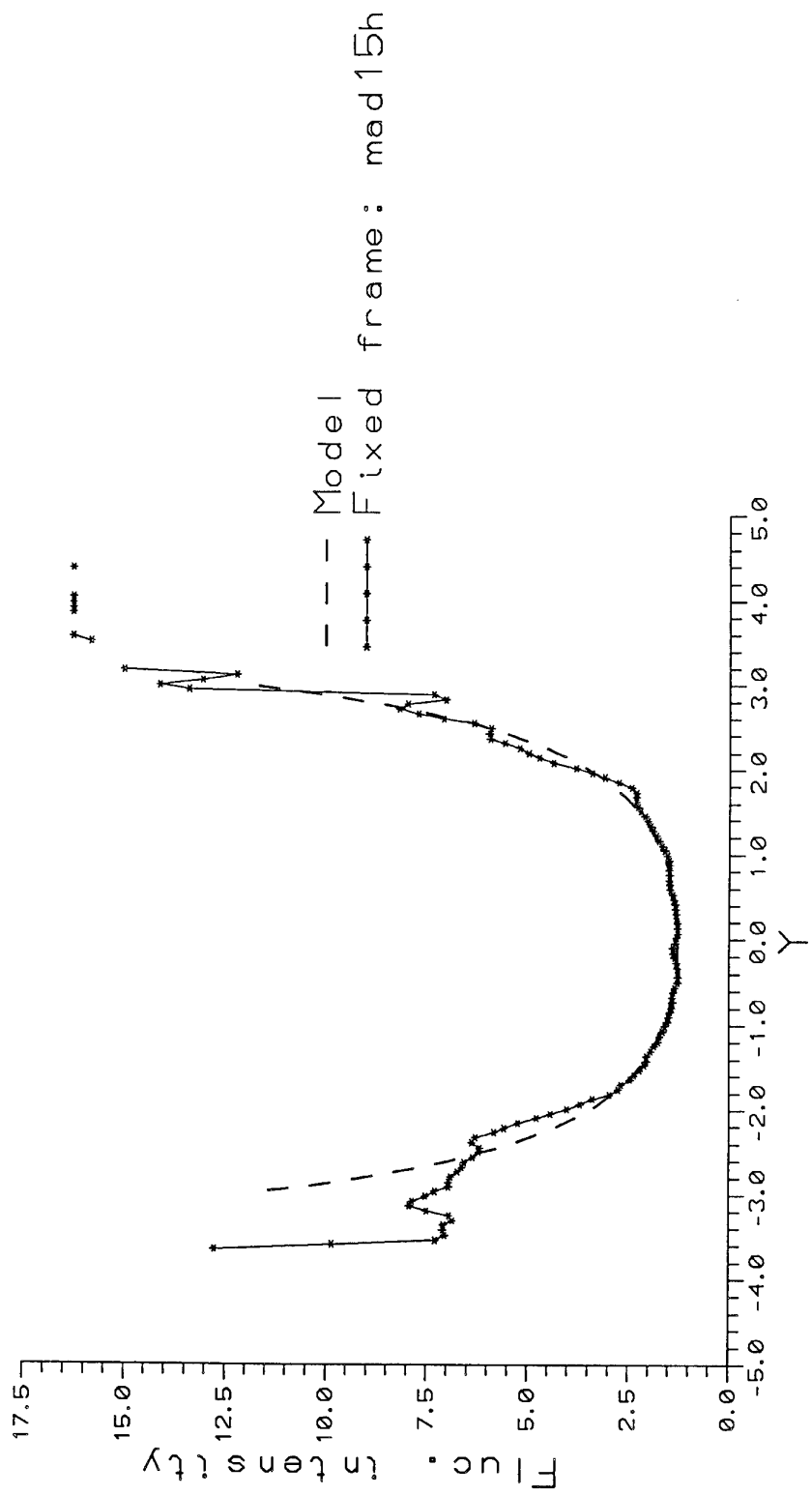


Figure III.2c



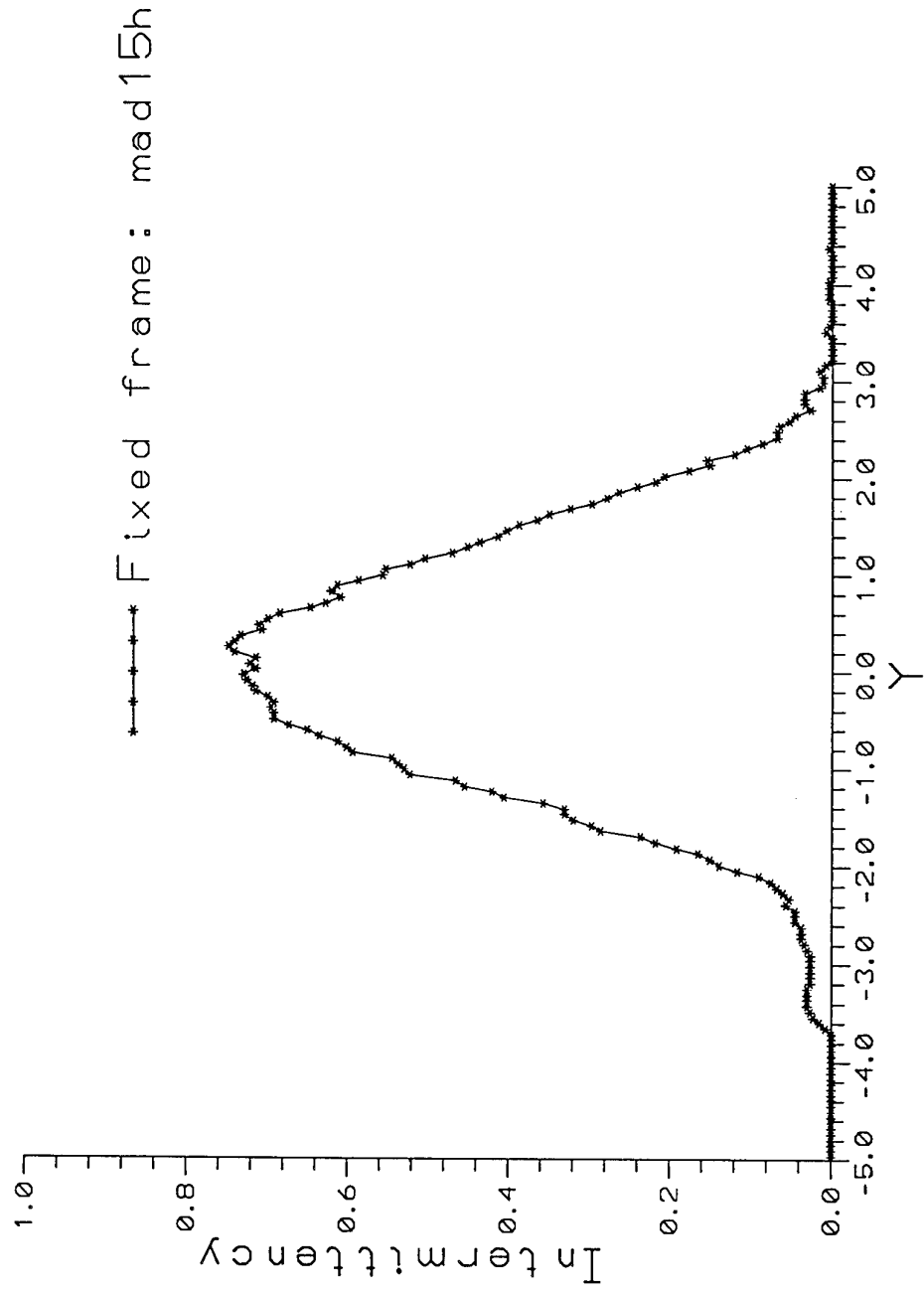


Figure III.2d

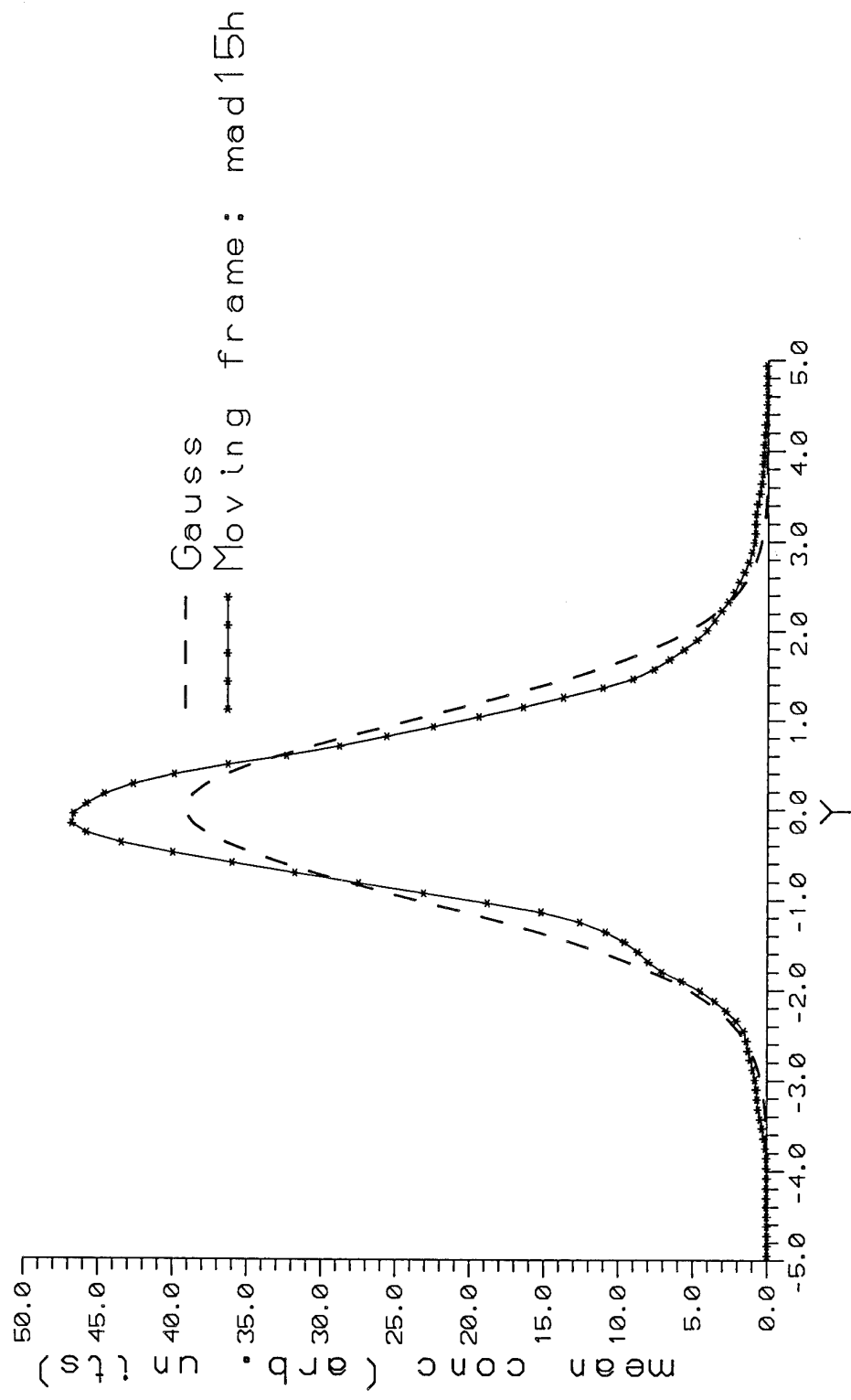
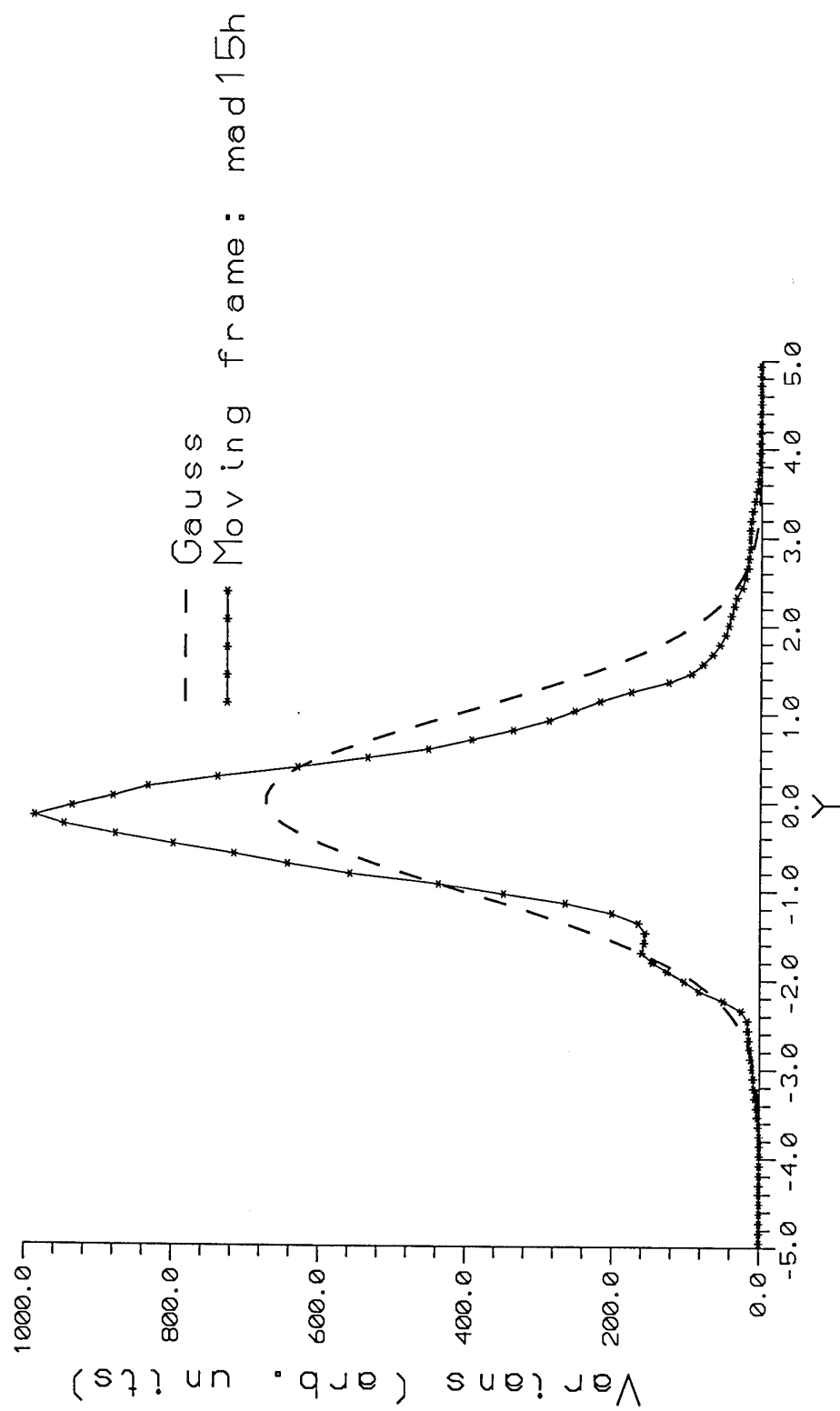


Figure III.3a

Figure III.3b



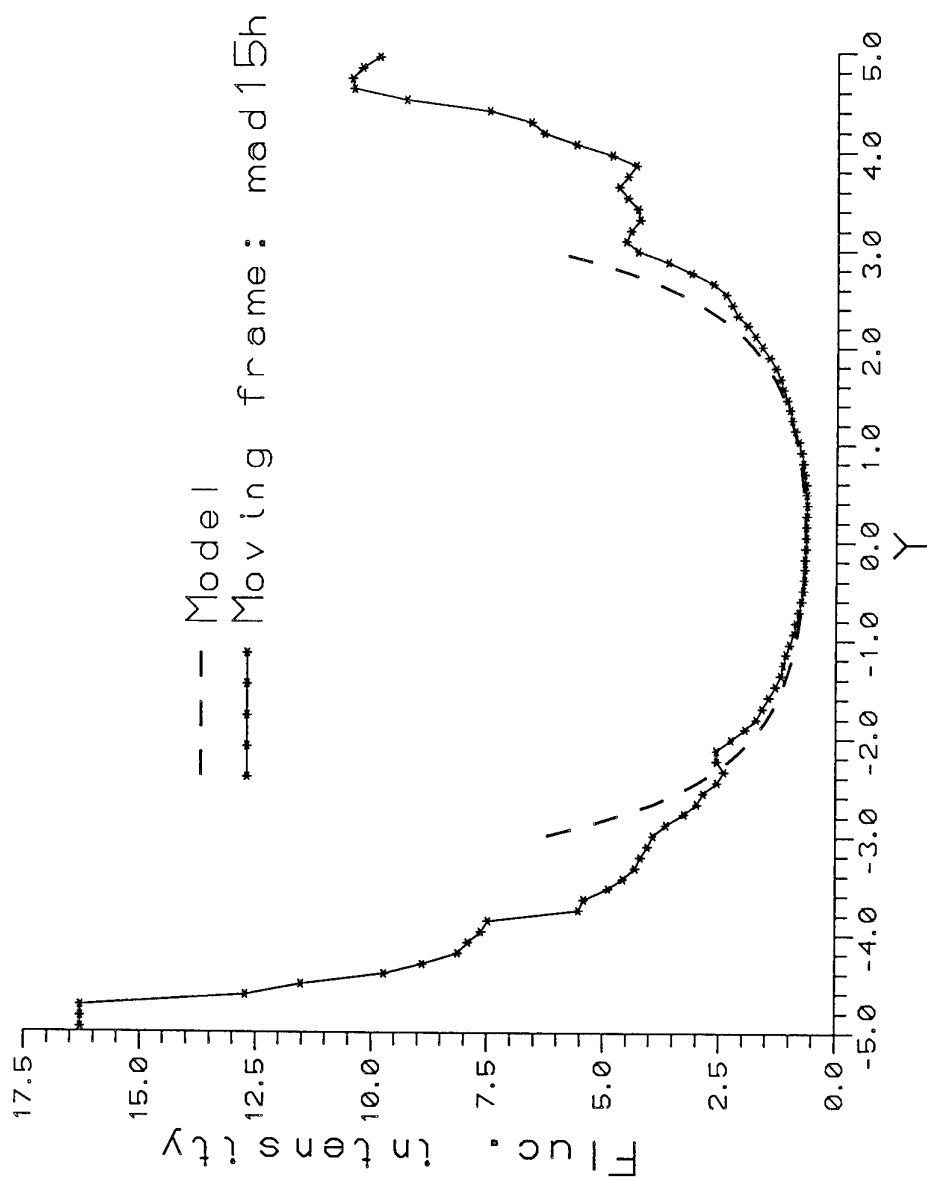


Figure III.3d

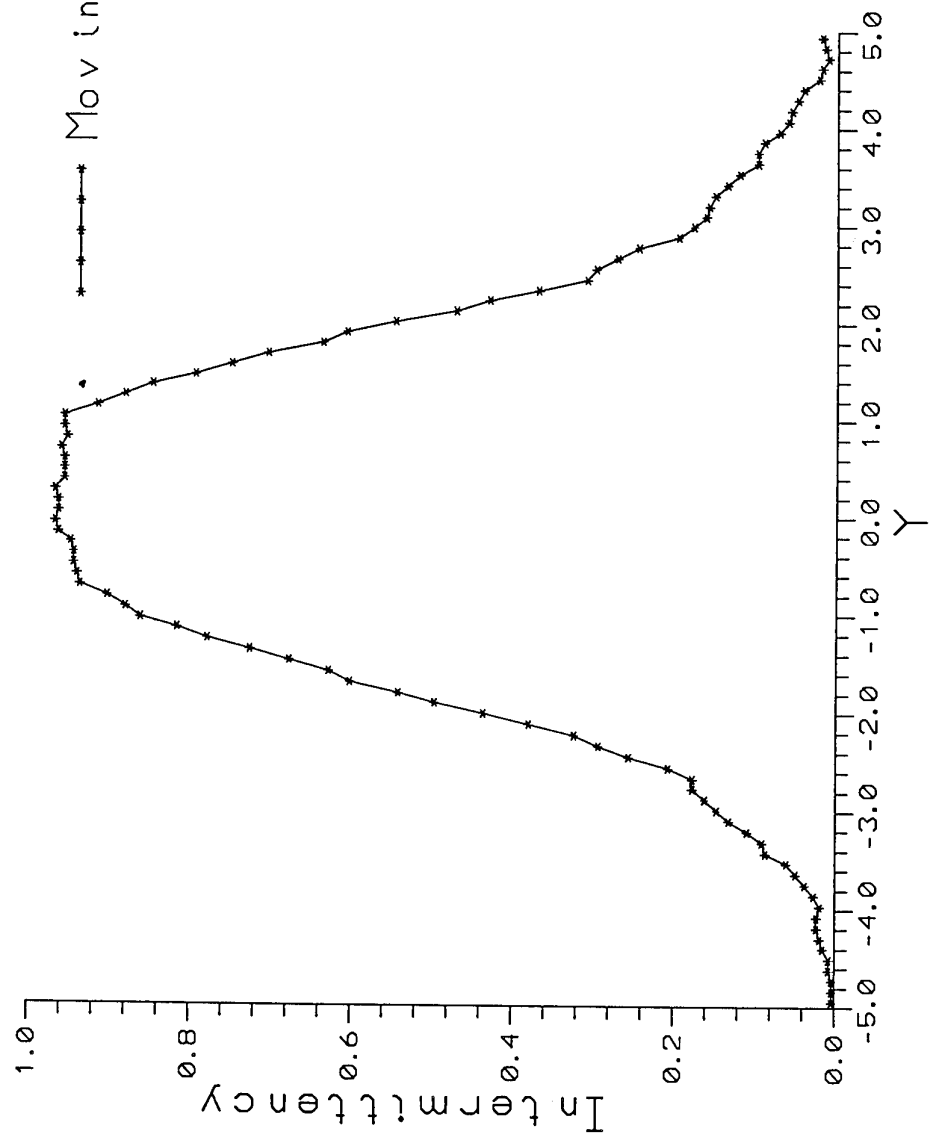
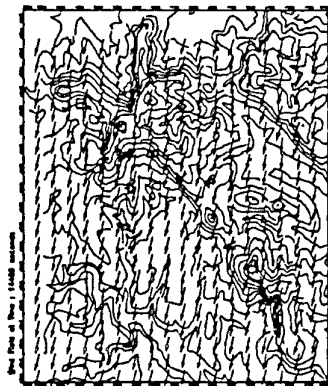
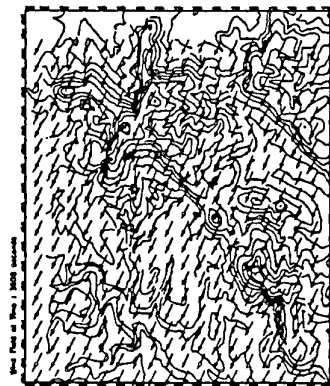
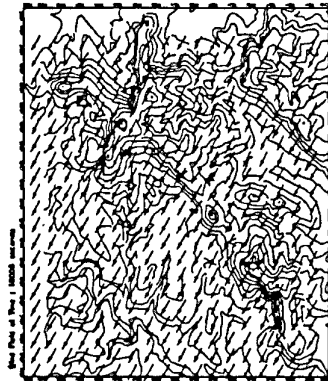
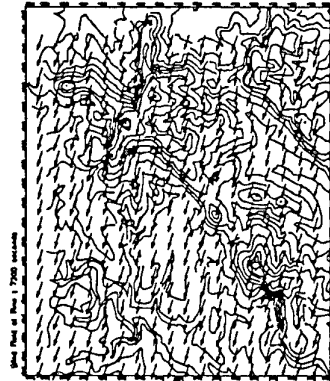
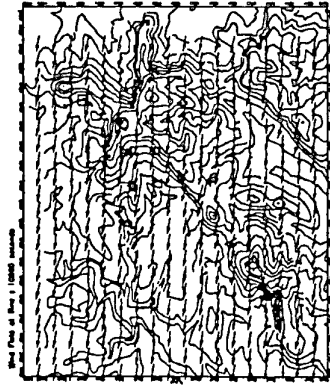


Figure IV.1. Lincom Flow Modelling

Porton  
September 17, 1992  
Release Time: 11:10 - 16:10  
Hourly fitted Windfields



# Porton

September 17, 1992  
Release Time: 11:10 - 16:10

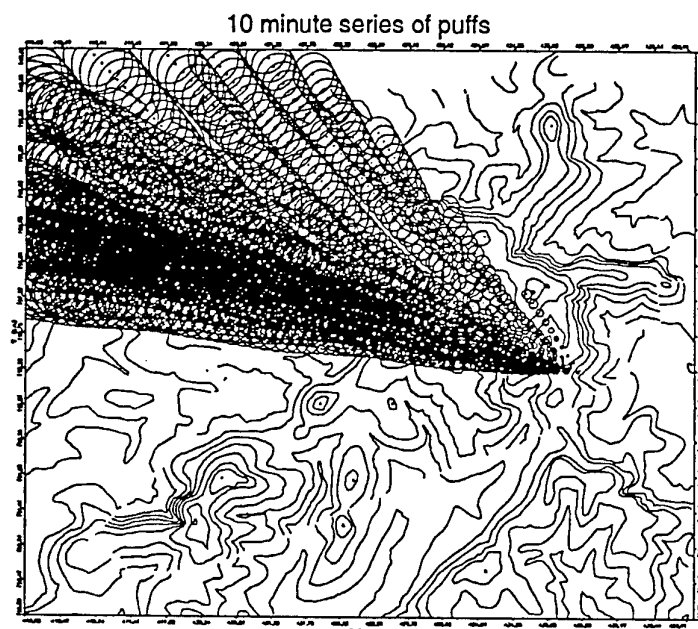


Figure IV.2

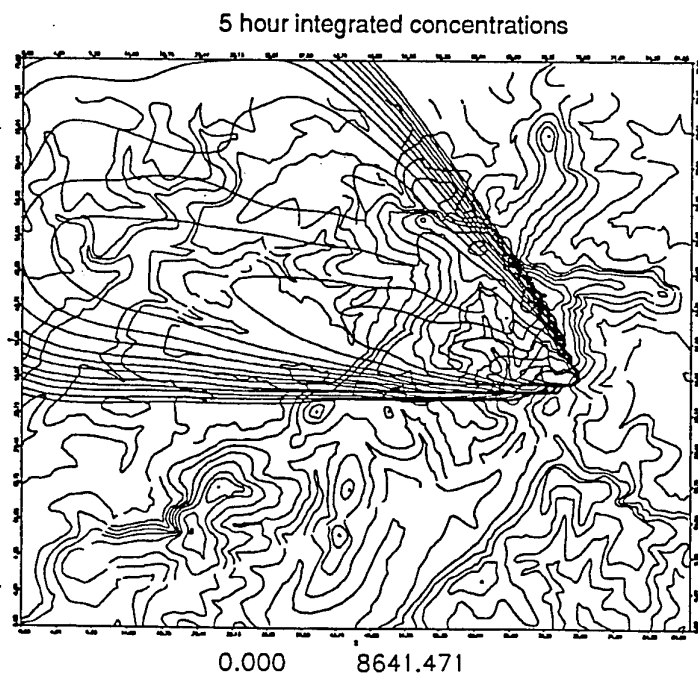


Figure IV.3

# PORTON TERRAIN ( X 20)

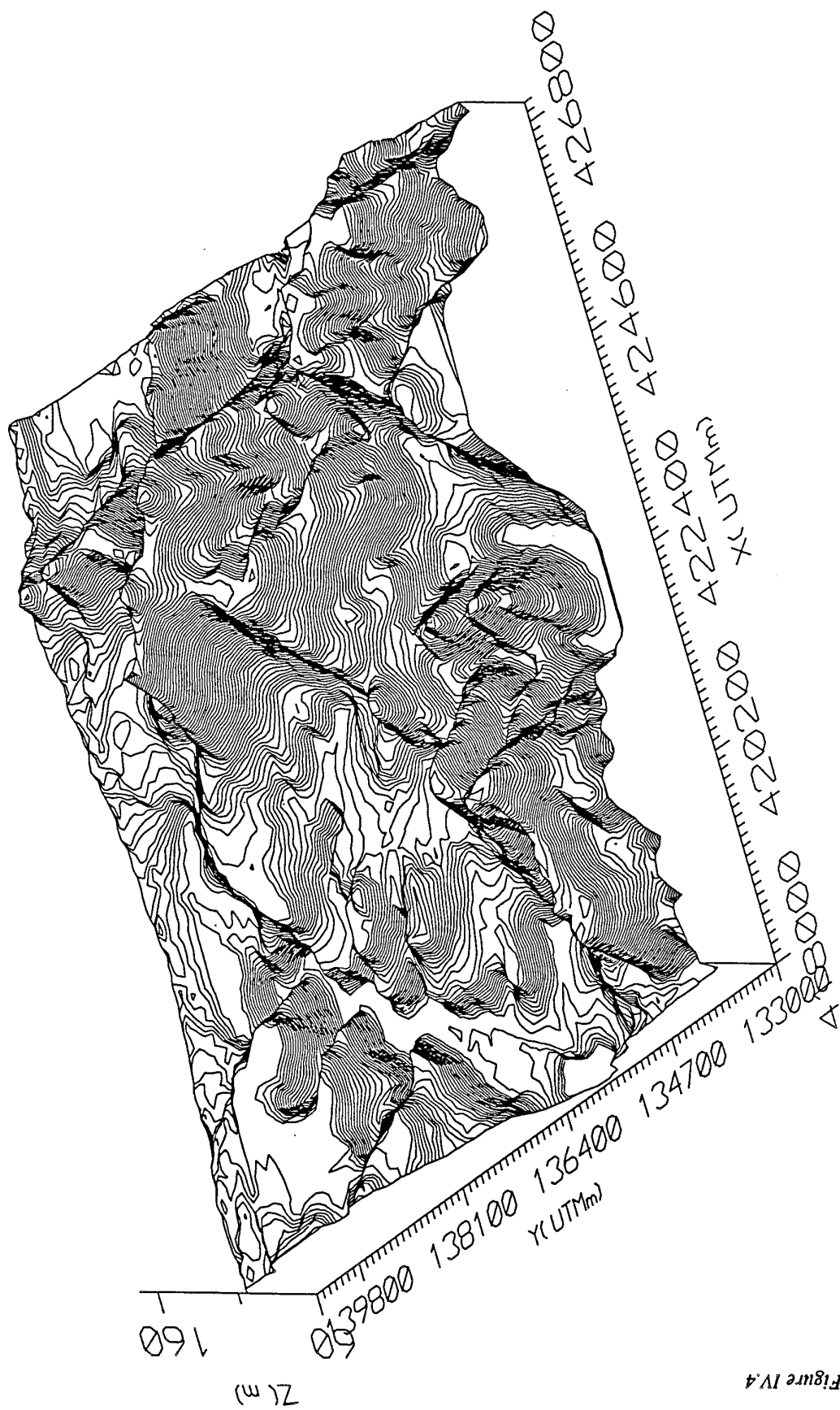


Figure IV.4

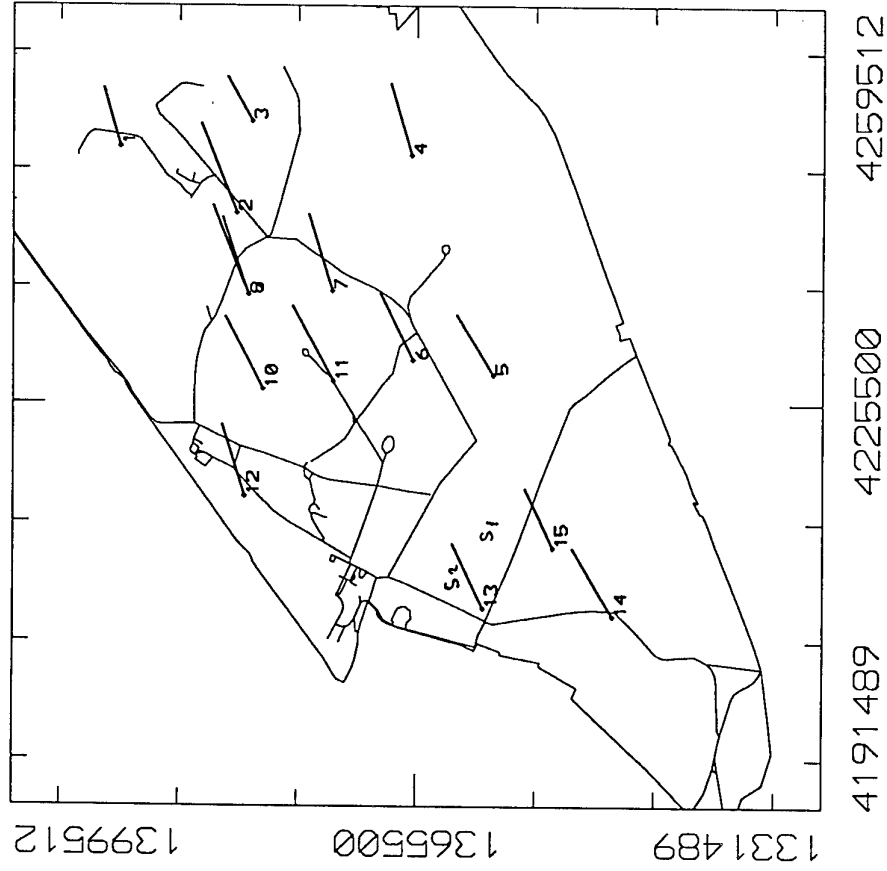


Figure IV.5

S, Oct '92

Plot: 16/4/1993

Tick distance: 10000

Value factor: 10000.000

Contrast step: 10000.000

Landscape file: ROADS.BLN

Map file: MASTS.MAP

Data file: 920912.VCT

Record: 1

Time: 12,11:05:00

S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BLN

Map file: LINCOM.MAP

Data file: LINCOM.VCT

Record: 3

Time: 0,00:20:00

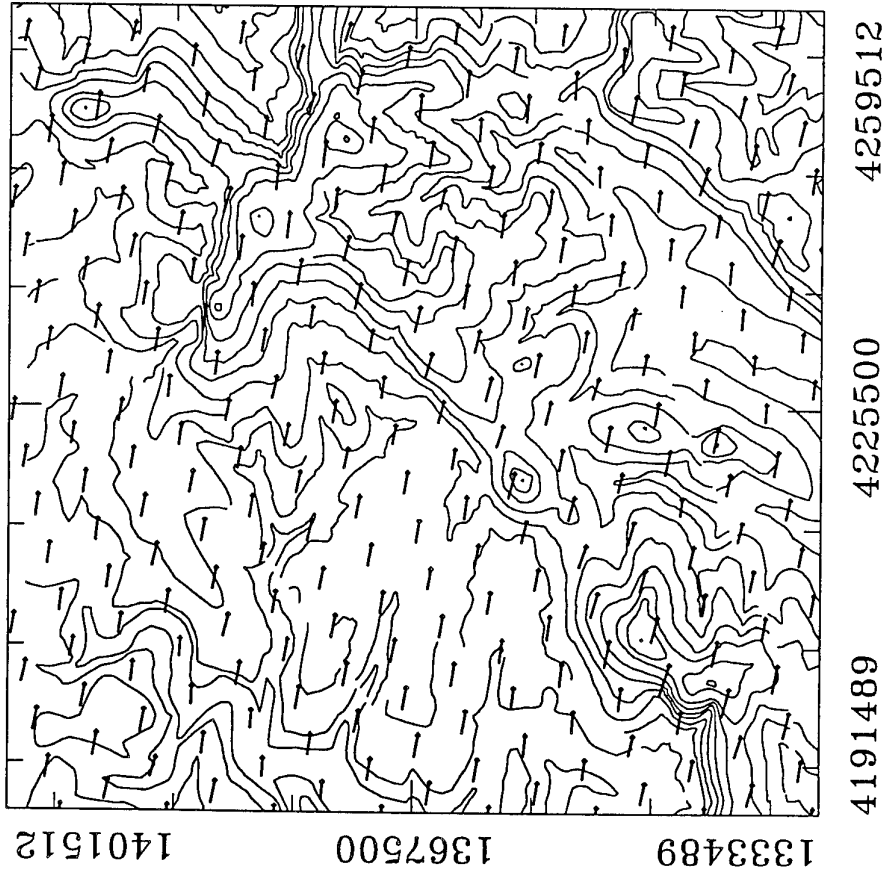


Figure IV.6

S,Oct'92  
Plot: 16/4/1993  
PORTON  
Tick distance: 10000  
Value factor: 1.000  
Contrast step: 1.000  
Landscape file: TERRAIN.BLN  
Map file: LINCOM.MAP  
Data file: LINCOM.VCT  
Record: 3  
Time: 0,00:20:00

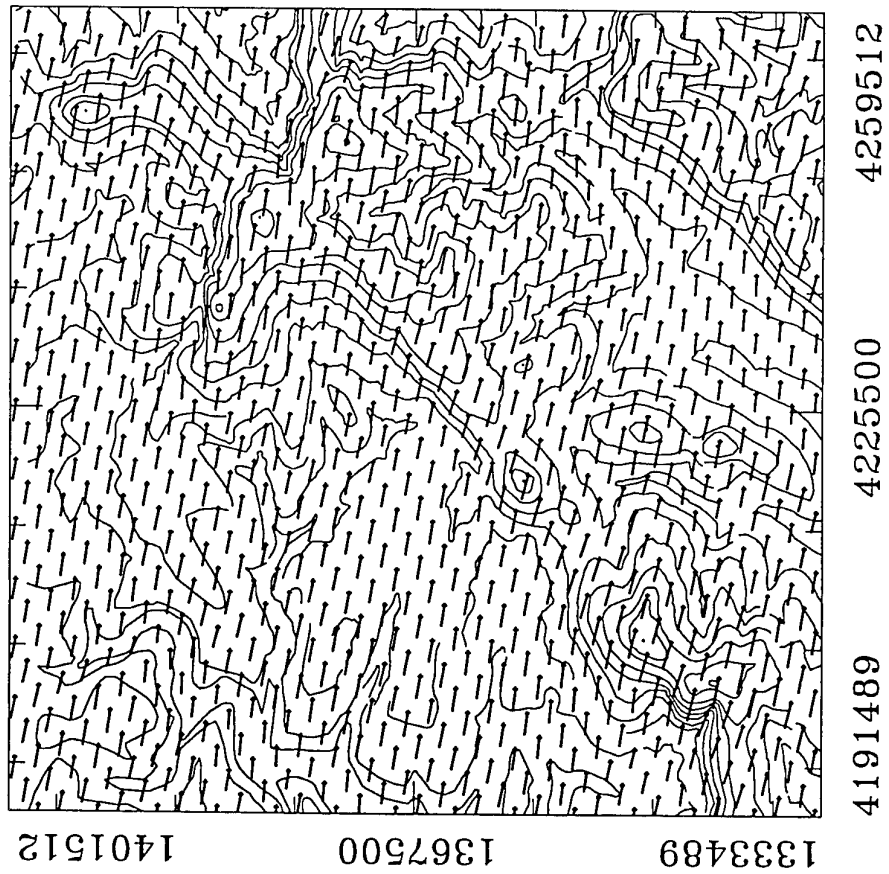


Figure IV.7

S,Oct'92

Plot: 16/4/1993

PORTON

Tick distance: 10000

Value factor: 1.000

Contrast step: 1.000

Landscape file: TERRAIN.BLN

Map file:

Data file: LINCOM.LNS

Record: 1

Time: 0,00:00:00

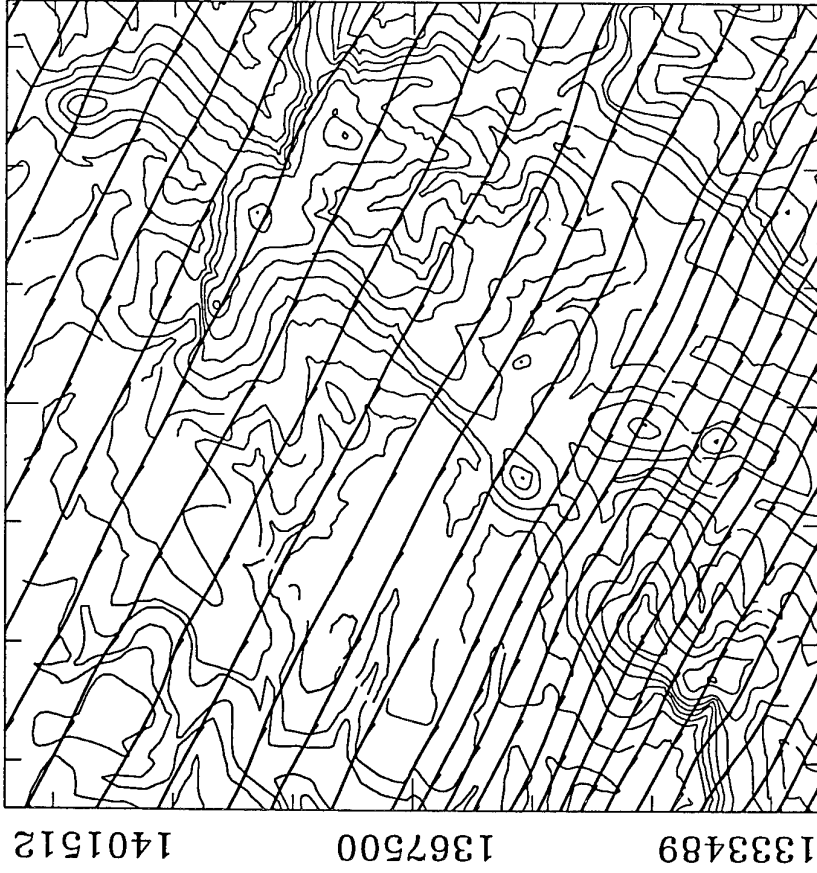


Figure IV.8

# Appendix IV

## Appendix V: The experimental log-book document "RUN\_DOC": (version 10.10.1993)

MADONA DISPERSION TRIAL SETUP FILE  
compiled by  
Kenneth Nyren, FOA and Harald Weber, GMGO

### Introduction

This ASCII file contains a compilation of the different runs performed during the ten day experimental period (14.9-23.9 1992) with both continuous smoke and instantaneously generated puffs. The experiments made in parallel with the tracer SF6 are also documented.

The task of collecting the necessary information in this file has been facilitated by personal trial logbooks.

The document is divided in three parts. These are:

- \* introduction
- \* syntax definition of the run file
- \* run documentation file

The purpose is to adopt a simple syntax in the run documentation with key words and values so as to make it machine readable. This has been achieved and proved to be an excellent way to validate the content of the file by plotting different runs on a simple map of the PORTON range.

ALL POSITIONS ARE MEASURED WITH A GPS50 NAVIGATOR FROM GARMIN.  
THE OGS 36 MAP DATUM HAS BEEN USED DURING THE TRIALS. THE POSITION ERROR IS ABOUT 18m, WHICH IS CONFIRMED INDEPENDENTLY BY COMPARISON WITH THE POSITION INDICATED AT THE TRIG. POINTS ON THE PORTON RANGE. THUS IT SHOULD BE KEPT IN MIND THAT BETTER POSITIONAL ACCURACY WAS NOT WITHIN THE SCOPE OF THE EXPERIMENTAL WORK.

Syntax definition of the run file

The simple syntax of the run documentation file is made by using the Backus-Naur form, syntactic constructs are denoted by English word enclosed between angular brackets <...>.

<run documentation file> ::= <run head> <data block> ...  
...<run head><data block>

<run head> ::=  
==> <run code> DURATION <run duration> RELEASE HEIGHT  
<release height> M

<data block> ::=  
RUN <date> <day> <release type>  
RELEASE TIME <release block inst> <release block cont.>  
WIND DIRECTION <value in deg>  
SOURCE <position>  
LIDAR DLR <position><bearing>  
LIDAR RISO <position><bearing>  
LIDAR UMIST <position><bearing>  
VIDEO GMGO <position><bearing>  
DATA FILES <file names>  
COMMENTS <text>  
WEATHER <text>

<run code> ::= R<julian date>IC<run no per day>  
<run duration> ::= <start time> - <stop time>  
<start time><stop time> ::= hh:mm  
<release height> ::= 9.9  
<release block cont.> ::= hh:dd - hh:dd SMOKE SF6  
<release block inst.> ::= hh:dd:ss SMOKE SF6  
<date> ::= dd.mm.yyyy  
<day> ::= MONDAYTUESDAY ...  
<release type> ::= INSTANTANEOUSCONTINUOUS  
<position> ::= dd.mm.mm.N ddd.mm.ss.sss.N Latitude  
99U WB 99999 99999 UTM Coordinate  
999999 999999 BNG Coordinate  
<bearing> ::= 999 Bearing  
<file names> ::= <RISO files> <DLR files> <GMGO files>  
<UMIST files>  
<GMGO files> ::= <SF6 files> <VIDEO profiles>

Run documentation file:

==> R25811 DURATION 13:38 - 14:28 RELEASE HEIGHT 2.3 M

RUN 14.09.1992 MONDAY Instantaneous

RELEASE TIME 13:38:30 SMOKE  
13:52:00 SMOKE  
14:00:15 SMOKE  
14:08:00 SMOKE  
14:18:15 SMOKE  
14:28:30 SMOKE

WIND DIRECTION 230

SOURCE :51\_07.54\_N 051\_07\_32.403\_N Latitude  
:01\_41.23\_W 001\_41\_13.800\_W Longitude  
30U WB 91875 64735 UTM Coordinate  
421889 136370 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07\_44.996\_N Latitude  
:01\_41.02\_W 001\_41\_01.200\_W Longitude  
422133 136760 BNG Coordinate  
30U WB 92113 65129 UTM Coordinate  
170 Bearing

LIDAR RISO :51\_07.71\_N 051\_07\_42.606\_N Latitude  
:01\_41.05\_W 001\_41\_02.999\_W Longitude  
422098 136686 BNG Coordinate  
30U WB 92079 65054 UTM Coordinate  
160 Bearing

VIDEO GMGO :51\_07.53\_N 051\_07\_31.799\_N Latitude  
:01\_41.25\_W 001\_41\_14.999\_W Longitude  
421866 136351 BNG Coordinate  
30U WB 91852 64716 UTM Coordinate  
110 Bearing

DATA FILES MAD14A 14-09-92.1  
MAD14B  
MAD14C  
MAD14D  
MAD14E  
MAD14F

==> R25812 DURATION 14:34 - 14:34 RELEASE HEIGHT 2.3 M

RUN 14.09.1992 MONDAY Instantaneous

RELEASE TIME 14:34:00

WIND DIRECTION 280

SOURCE :51\_07.56\_N 051\_07\_33.598\_N Latitude  
:01\_41.22\_W 001\_41\_13.200\_W Longitude  
30U WB 91886 64773 UTM Coordinate  
421901 136407 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07\_44.996\_N Latitude  
:01\_41.02\_W 001\_41\_01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
170 Bearing

LIDAR RISO :51\_07.71\_N 051\_07\_42.606\_N Latitude  
:01\_41.05\_W 001\_41\_02.999\_W Longitude  
30U WB 92079 65054 UTM Coordinate  
422098 136686 BNG Coordinate  
160 Bearing

VIDEO GMGO :51\_07.53\_N 051\_07\_31.799\_N Latitude  
:01\_41.25\_W 001\_41\_14.999\_W Longitude  
30U WB 91852 64716 UTM Coordinate  
421866 136351 BNG Coordinate  
110 Bearing

DATA FILES MAD14G

==> R258C1 DURATION 15:28 - 17:48 RELEASE HEIGHT 1.0 M

RUN 14.09.1992 MONDAY Continuous

RELEASE TIME 15:28:00 - 17:48:00 SF6  
16:30:00 - 17:00:00 SMOKE  
17:15:00 - 17:48:00 SMOKE

WIND DIRECTION 280

SOURCE :51\_07.57\_N 051\_07.34.202\_N Latitude  
:01\_41.25\_W 001\_41.14.999\_W Longitude  
30U WB 91850 64791 UTM Coordinate  
421866 136425 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
190 Bearing

LIDAR RISO :51\_07.71\_N 051\_07.42.606\_N Latitude  
:01\_41.05\_W 001\_41.02.999\_W Longitude  
30U WB 92079 65054 UTM Coordinate  
422098 136686 BNG Coordinate  
190 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
190 Bearing

DATA FILES MAD14H 14-09-92.2 C141612F  
MAD14I 14-09-92.3 C141617F  
MAD14J 14-09-92.4 C141623F  
MAD14K C141627F  
C141646F  
C141654F  
C141701F  
C141707F  
C141718F  
C141724F  
C141732F  
C141738F

COMMENTS Smoke stopped at 17:02. Restart at 17:15  
continuing until 17:43.

WEATHER Trial 1, JD258, 14 Sep had overcast skies  
producing neutral stability conditions with SW  
winds of 7 to 10 m/s resulting in a good met.  
case, a marginal met. modeling situation and good  
concentration situation.

==>R25911 DURATION 13:29 - 17:48 RELEASE HEIGHT 2.9 M

RUN 15.09.1992 TUESDAY Instantaneous

RELEASE TIME 13:29:00 SMOKE  
13:38:50 SMOKE  
13:45:17 SMOKE  
13:53:00 SMOKE  
14:01:30 SMOKE  
14:09:00 SMOKE  
14:15:30 SMOKE

WIND DIRECTION 230

SOURCE :51\_07.52\_N 051\_07.31.194\_N Latitude  
:01\_41.16\_W 001\_41.09.599\_W Longitude  
30U WB 91957 64700 UTM Coordinate  
421971 136333 BNG Coordinate

LIDAR DLR :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65111 UTM Coordinate  
422133 136741 BNG Coordinate  
140 Bearing

LIDAR RISO :51\_07.71\_N 051\_07.42.606\_N Latitude  
:01\_41.07\_W 001\_41.04.199\_W Longitude  
30U WB 92056 65054 UTM Coordinate  
422075 136686 BNG Coordinate  
140 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
185 - 145 Bearing

VIDEO GMGO :51\_07.51\_N 051\_07.30.604\_N Latitude  
:01\_41.19\_W 001\_41.11.399\_W Longitude  
30U WB 91922 64681 UTM Coordinate  
421936 136314 BNG Coordinate  
050 Bearing

DATA FILES MAD15A 15-09-92.P1  
MAD15B  
MAD15C  
MAD15D  
MAD15E  
MAD15F  
MAD15G

COMMENTS Puffs passing HS area with Dugway sonics

==> R259C1 DURATION 14:47 - 16:47 RELEASE HEIGHT 1.0 M

RUN 15.09.1992 TUESDAY Continuous

RELEASE TIME 14:47:00 - 16:47:00 SMOKE SF6

WIND DIRECTION 230

SOURCE :51\_07.52\_N 051\_07.31.194\_N Latitude  
:01\_41.16\_W 001\_41.09.599\_W Longitude  
30U WB 91957 64700 UTM Coordinate  
421971 136333 BNG Coordinate

LIDAR DLR :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65111 UTM Coordinate  
422133 136741 BNG Coordinate  
140 Bearing

LIDAR RISO :51\_07.71\_N 051\_07.42.606\_N Latitude  
:01\_41.07\_W 001\_41.04.199\_W Longitude  
30U WB 92056 65054 UTM Coordinate  
422075 136686 BNG Coordinate  
140 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
185 - 145 Bearing

VIDEO GMGO :51\_07.71\_N 051\_07.42.606\_N Latitude  
:01\_41.07\_W 001\_41.04.199\_W Longitude  
30U WB 92056 65054 UTM Coordinate  
422075 136686 BNG Coordinate  
140 Bearing

DATA FILES MAD15H 15-09-92.1 C151504F  
MAD15I 15-09-92.2 C151517F  
MAD15J 15-09-92.3 C151522F  
MAD15K C151525F  
MAD15L C151532F  
C151538F  
C151542F  
C151551F  
C151614F  
C151621F  
C151632F  
C151642F  
C151649F

==> R259I2 DURATION 17:19 - 17:48 RELEASE HEIGHT 2.9M

RUN 15.09.1992 TUESDAY Instantaneous

RELEASE TIME 17:19:00 SMOKE  
17:27:00 SMOKE

17:37:30 SMOKE  
17:48:10 SMOKE

WIND DIRECTION 230

SOURCE :51\_07.52\_N 051\_07.31.194\_N Latitude  
:01\_41.16\_W 001\_41.09.599\_W Longitude  
30U WB 91957 64700 UTM Coordinate  
421971 136333 BNG Coordinate

LIDAR DLR :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65111 UTM Coordinate  
422133 136741 BNG Coordinate  
140 Bearing

LIDAR RISO :51\_07.71\_N 051\_07.42.606\_N Latitude  
:01\_41.07\_W 001\_41.04.199\_W Longitude  
30U WB 92056 65054 UTM Coordinate  
422075 136686 BNG Coordinate  
140 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
185 - 145 Bearing

VIDEO GMGO :51\_07.51\_N 051\_07.30.604\_N Latitude  
:01\_41.19\_W 001\_41.11.399\_W Longitude  
30U WB 91922 64681 UTM Coordinate  
421936 136314 BNG Coordinate  
050 Bearing

DATA FILES MAD15M 15-09-92.P1  
-- 15-09-92.P2  
--  
MAD15N

COMMENTS Only the first puff and the last puff where traced by  
LIDAR RISO

WEATHER Trial 2, JD259, 15 Sep had overcast skies again  
producing neutral and some unstable conditions with SW  
winds 8 to 5 m/s resulting in a good met. case,  
a marginal met. modeling situation, and good  
concentration situation.

==> R260C1 DURATION 13:31 - 15:54 RELEASE HEIGHT 1  
M

RUN 16.09.1992 WEDNESDAY Continuous

RELEASE TIME 13:31 - 15:54 SF6

WIND DIRECTION 130

SOURCE :51\_07.80\_N 051\_07.48.003\_N Latitude  
:01\_39.92\_W 001\_39.55.199\_W Longitude  
30U WB 93394 65245 UTM Coordinate  
423415 136858 BNG Coordinate

DATA FILES C161350F  
C161417F  
C161427F  
C161439F  
C161503F  
C161520F  
C161542F

COMMENTS This continuous SF6 release run in parallel with the  
following instantaneous smoke release.

==> R260I1 DURATION 14:04 - 15:02 RELEASE HEIGHT 1 M

RUN 16.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 14:04:00 SMOKE  
14:34:45 SMOKE  
14:51:20 SMOKE  
15:02:10 SMOKE

WIND DIRECTION 130

SOURCE :51\_07.80\_N 051\_07.48.003\_N Latitude  
:01\_39.92\_W 001\_39.55.199\_W Longitude  
30U WB 93394 65245 UTM Coordinate  
423415 136858 BNG Coordinate

LIDAR DLR :51\_07.78\_N 051\_07.46.795\_N Latitude  
:01\_39.89\_W 001\_39.53.399\_W Longitude  
30U WB 93429 65208 UTM Coordinate  
423450 136821 BNG Coordinate  
302 Bearing

LIDAR RISO :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_40.27\_W 001\_40.16.199\_W Longitude  
30U WB 92988 65126 UTM Coordinate  
423007 136745 BNG Coordinate  
053 Bearing

VIDEO GMGO :51\_07.78\_N 051\_07.46.795\_N Latitude  
:01\_39.89\_W 001\_39.53.399\_W Longitude  
30U WB 93429 65208 UTM Coordinate  
423450 136821 BNG Coordinate  
302 Bearing

DATA FILES MAD16A 16-09-92.P1  
MAD16B  
MAD16C  
MAD16D

COMMENTS DLR LIDAR FROM BEHIND AND 14:04:00 AT  
51\_07.78\_N  
1\_39.92\_W ONLY. FIRST PUFF 5-6 M ABOVE GROUND

==> R260I2 DURATION 16:00 - 18:42 RELEASE HEIGHT 1.0

RUN 16.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 16:00:00 SMOKE  
16:15:30 SMOKE  
16:26:00 SMOKE SF6  
16:39:15 SMOKE SF6  
16:52:15 SMOKE SF6  
17:04:30 SMOKE SF6  
17:18:00 SMOKE SF6  
17:30:00 SMOKE SF6  
17:48:45 SMOKE SF6  
18:12:50 SMOKE SF6  
18:42:32 SMOKE SF6

WIND DIRECTION 135

SOURCE :51\_07.80\_N 051\_07.48.003\_N Latitude  
:01\_39.92\_W 001\_39.55.199\_W Longitude  
30U WB 93394 65245 UTM Coordinate  
423415 136858 BNG Coordinate

LIDAR DLR :51\_07.78\_N 051\_07.46.795\_N Latitude  
:01\_39.89\_W 001\_39.53.399\_W Longitude  
30U WB 93429 65208 UTM Coordinate  
423450 136821 BNG Coordinate  
350 Bearing

LIDAR RISO :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_40.27\_W 001\_40.16.199\_W Longitude  
30U WB 92988 65126 UTM Coordinate  
423007 136745 BNG Coordinate  
053 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
185 - 145 Bearing

VIDEO GMGO :51\_07.78\_N 051\_07.46.795\_N Latitude  
:01\_39.89\_W 001\_39.53.399\_W Longitude  
30U WB 93429 65208 UTM Coordinate  
423450 136821 BNG Coordinate  
350 Bearing

DATA FILES MAD16G 16-09-92.P1 C161652P  
MAD16H C161704P  
MAD16I C161718P C161804F  
MAD16J C161813P  
MAD16K C161848P  
MAD16L C161858P  
MAD16M  
MAD16N  
MAD16O

COMMENTS 17:04 WINDSPEED 0.5 M/S WINDDIR 220 DEG  
17:20-17:44 UMIST LIDAR SCANNING IN 095-055 DEG

WEATHER Trial 3, JD260, 16 Sep had clear skies producing,

unstable, neutral and stable conditions with SE winds  
5 m/s resulting in a very good met. case, an excellent  
modeling situation, and good puff concentrations.

==>R261I0 DURATION - RELEASE HEIGHT - M

NORUN 17.09.1992 THURSDAY

WEATHER: Trial 4, JD261, 17 Sep had overcast skies producing  
neutral stability conditions and E and SE winds of  
5 to 1 m/s resulting in a good met for modeling,  
but poor met conditions for tracer releases - unable  
to maintain a steady wind direction thereby  
compromising the positioning of the tracer/lidar sets.

==> R262C1 DURATION 13:45 - 14:13 RELEASE HEIGHT 1 M

RUN 18.09.1992 FRIDAY Continuous

RELEASE TIME 13:35:00 - 14:40:00 SMOKE  
13:35:00 - 16:50:00 SF6

WIND DIRECTION 225

SOURCE :51\_07.61\_N 051\_07.36.605\_N Latitude  
:01\_41.24\_W 001\_41.14.400\_W Longitude  
30U WB 91861 64865 UTM Coordinate  
421877 136499 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.01\_W 001\_41.00.600\_W Longitude  
30U WB 92124 65129 UTM Coordinate  
422144 136760 BNG Coordinate  
087 Bearing

DATA FILES 18-09-92.1 C181402F  
C181406F  
C181414F  
C181426F  
C181434F  
C181450F  
C181537F

COMMENTS Owing to precipitation RISO LIDAR unable to run

==> R262II DURATION 17:02 - 17:32 RELEASE HEIGHT 2.3 M

RUN 18.09.1992 FRIDAY Instantaneous

RELEASE HEIGHT 2.3 M

RELEASE TIME 17:02:20 SMOKE  
17:13:00 SMOKE  
17:19:30 SMOKE  
17:32:00 SMOKE SF6

WIND DIRECTION 220

SOURCE :51\_07.43\_N 051\_07.25.797\_N Latitude  
:01\_40.75\_W 001\_40.44.999\_W Longitude  
30U WB 92438 64541 UTM Coordinate  
422450 136168 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.01\_W 001\_41.00.600\_W Longitude  
30U WB 92124 65129 UTM Coordinate  
422144 136760 BNG Coordinate  
087 Bearing

LIDAR RISO :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_40.88\_W 001\_40.52.799\_W Longitude  
30U WB 92276 65113 UTM Coordinate  
422296 136742 BNG Coordinate  
065 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
185 - 145 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
050 Bearing

DATA FILES 18-09-92.P1

==>R262C2 DURATION 17:42 - 18:42 RELEASE HEIGHT 1.0 M

RUN 18.09.1992 FRIDAY Continuous

RELEASE TIME 17:42:00 - 18:42:00 SMOKE SF6

WIND DIRECTION 180

SOURCE :51\_07.50\_N 051\_07.29.999\_N Latitude  
:01\_40.56\_W 001\_40.33.599\_W Longitude  
30U WB 92657 64675 UTM Coordinate  
422671 136299 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.01\_W 001\_41.00.600\_W Longitude  
30U WB 92124 65129 UTM Coordinate  
422144 136760 BNG Coordinate  
087 Bearing

LIDAR RISO :51\_07.74\_N 051\_07.44.405\_N Latitude  
:01\_40.88\_W 001\_40.52.799\_W Longitude  
30U WB 92276 65113 UTM Coordinate  
422296 136742 BNG Coordinate  
065 Bearing

LIDAR UMIST :51\_08.02\_N 051\_08.01.201\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65634 UTM Coordinate  
422375 137261 BNG Coordinate  
085 - 125 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.01\_W 001\_41.00.600\_W Longitude  
30U WB 92124 65129 UTM Coordinate  
422144 136760 BNG Coordinate  
087 Bearing

DATA FILES MAD18A 18-09-92.P1 C181803F  
C181810F  
C181824F  
C181837F  
C181858F

WEATHER Trial 5, JD262, 18 Sep had overcast skies producing  
neutral stability conditions with SE winds of 4 to  
1 m/s resulting in a very good met and modelling  
situation and good concentration situation.

==> R263II DURATION 13:15 - 14:01 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE TIME 13:15:00 SMOKE SF6  
13:25:00 SMOKE SF6  
13:36:00 SMOKE SF6  
13:47:23 SMOKE SF6  
14:01:00 SMOKE SF6

WIND DIRECTION 300

SOURCE :51\_07.69\_N 051\_07.41.398\_N Latitude  
:01\_41.27\_W 001\_41.16.199\_W Longitude  
30U WB 91823 65012 UTM Coordinate  
421842 136647 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.01\_W 001\_41.00.600\_W Longitude  
30U WB 92124 65129 UTM Coordinate  
422144 136760 BNG Coordinate  
221 Bearing

LIDAR RISO :51\_07.69\_N 051\_07.41.398\_N Latitude  
:01\_41.04\_W 001\_41.02.400\_W Longitude  
30U WB 92091 65017 UTM Coordinate  
422110 136648 BNG Coordinate  
221 Bearing

VIDEO GMGO :51\_07.70\_N 051\_07.42.002\_N Latitude  
:01\_41.29\_W 001\_41.17.399\_W Longitude  
30U WB 91799 65031 UTM Coordinate  
421818 136666 BNG Coordinate  
135 Bearing

DATA FILES MAD19A 19-09-92.1 C191325P  
MAD19B C191336P  
MAD19C C191347P  
MAD19D C191401P  
MAD19E

==>R263C1 DURATION 14:50 - 15:55 RELEASE HEIGHT 1.0 M

RUN 19.09.1992 SATURDAY Continuous

RELEASE TIME 14:50:00 - 15:55:00 SMOKE SF6

WIND DIRECTION 270

SOURCE :51\_07.81\_N 051\_07.48.594\_N Latitude  
:01\_41.12\_W 001\_41.07.199\_W Longitude  
30U WB 91994 65238 UTM Coordinate  
422016 136870 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_40.77\_W 001\_40.46.199\_W Longitude  
30U WB 92404 65134 UTM Coordinate  
422424 136761 BNG Coordinate  
003 Bearing

LIDAR RISO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_40.77\_W 001\_40.46.199\_W Longitude  
30U WB 92404 65134 UTM Coordinate  
422424 136761 BNG Coordinate  
003 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_40.77\_W 001\_40.46.199\_W Longitude  
30U WB 92404 65134 UTM Coordinate  
422424 136761 BNG Coordinate  
003 Bearing

DATA FILES MAD19E 19-09-92.1 C191454F  
C191516F  
C191521F  
C191524F  
C191529F  
C191548F  
C191600F

==> R263I2 DURATION 16:10 - 16:26 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE HEIGHT 6 M

RELEASE TIME 16:10:40 SMOKE SF6  
16:20:30 SMOKE SF6  
16:26:35 SMOKE SF6

WIND DIRECTION 280

SOURCE :51\_07.81\_N 051\_07.48.594\_N Latitude  
:01\_41.12\_W 001\_41.07.199\_W Longitude  
30U WB 91994 65238 UTM Coordinate  
422016 136870 BNG Coordinate

LIDAR DLR :51\_07.95\_N 051\_07.56.998\_N Latitude  
:01\_40.67\_W 001\_40.40.199\_W Longitude  
30U WB 92514 65507 UTM Coordinate  
422539 137132 BNG Coordinate  
330 Bearing

LIDAR RISO :51\_07.95\_N 051\_07.56.998\_N Latitude  
:01\_40.67\_W 001\_40.40.199\_W Longitude  
30U WB 92514 65507 UTM Coordinate  
422539 137132 BNG Coordinate  
330 Bearing

DATA FILES MAD19F 19-09-92.1  
-- C191620P  
MAD19G

==> R263I3 DURATION 17:35 - 18:30 RELEASE HEIGHT 6 M

RUN 19.09.1992 SATURDAY Instantaneous

RELEASE TIME 17:35:00 SMOKE  
17:49:30 SMOKE  
18:01:00 SMOKE  
18:14:30 SMOKE  
18:23:00 SMOKE  
18:30:00 SMOKE

WIND DIRECTION 225

SOURCE :51\_08.00\_N 051\_08.00.006\_N Latitude  
:01\_40.81\_W 001\_40.48.600\_W Longitude  
30U WB 92349 65597 UTM Coordinate

422376 137224 BNG Coordinate

LIDAR DLR :51\_07.95\_N 051\_07.56.998\_N Latitude  
:01\_40.67\_W 001\_40.40.199\_W Longitude  
30U WB 92514 65507 UTM Coordinate  
422539 137132 BNG Coordinate  
330 Bearing

LIDAR RISO :51\_07.95\_N 051\_07.56.998\_N Latitude  
:01\_40.67\_W 001\_40.40.199\_W Longitude  
30U WB 92514 65507 UTM Coordinate  
422539 137132 BNG Coordinate  
330 Bearing

VIDEO CBDE :51\_07.73\_N 051\_07.43.801\_N Latitude  
:01\_40.28\_W 001\_40.16.799\_W Longitude  
30U WB 92976 65107 UTM Coordinate  
422996 136727 BNG Coordinate  
320 Bearing

DATA FILES -- 19-09-92.1  
MAD19H C191745F  
MAD19I  
MAD19J  
MAD19K  
MAD19L

COMMENTS FROM 17:50 STABLE CONDITIONS High extinction  
and low backscatter

WEATHER Trial 6, JD263, 19 Sep had overcast skies with some  
breaks producing instable, neutral and stable stability  
conditions with W and SW winds of 5 to 1 m/s resulting  
in very good met and modelling and good puff  
concentration conditions.

==> R264C1 DURATION 11:40 - 13:20 RELEASE HEIGHT 1 M

RUN 20.09.1992 SUNDAY Continuous

RELEASE TIME 11:40:00 - 13:20:00 SMOKE SF6

WIND DIRECTION 225

SOURCE :51\_07.42\_N 051\_07.25.193\_N Latitude  
:01\_41.04\_W 001\_41.02.400\_W Longitude  
30U WB 92100 64517 UTM Coordinate  
422112 136148 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
120 Bearing

LIDAR RISO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_40.49\_W 001\_40.29.399\_W Longitude  
30U WB 92731 65140 UTM Coordinate  
422751 136762 BNG Coordinate  
310 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
120 Bearing

DATA FILES MAD20A 20-09-92.1 C201141F  
C201153F  
C201205F  
C201218F  
C201225F  
C201240F  
MAD20B C201246F  
C201253F

COMMENTS 12:07--12:29 Very bad lidar profiles caused by smoke  
into LIDAR. RISO LIDAR position uncertain  
12:47--13:01 Not too bad

==> R264I1 DURATION 14:55 - 15:30 RELEASE HEIGHT 6 M

RUN 20.09.1992 SUNDAY Instantaneous

RELEASE TIME 14:55:22 SMOKE  
15:13:30 SMOKE SF6  
15:30:00 SMOKE SF6

WIND DIRECTION 225

SOURCE :51\_07.53\_N 051\_07.31.799\_N Latitude  
:01\_41.16\_W 001\_41.09.599\_W Longitude  
30U WB 91957 64718 UTM Coordinate  
421971 136351 BNG Coordinate LIDAR DLR  
:51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
120 Bearing

LIDAR RISO :51\_07.70\_N 051\_07.42.002\_N Latitude  
:01\_41.03\_W 001\_41.01.800\_W Longitude  
30U WB 92103 65036 UTM Coordinate  
422121 136667 BNG Coordinate  
120 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
120 Bearing

DATA FILES MAD20C 20-09-92.1  
MAD20D C201513P  
MAD20E

COMMENTS 15:30 THE HOLLY PUFF WAS RELEASED

==>R264C2 RELEASE TIME 15:40-16:00 RELEASE HEIGHT1 M

RUN 20.09.1992 SUNDAY Continuous

RELEASE HEIGHT 1 M

RELEASE TIME 15:40:00 - 16:00:00 SF6

WIND DIRECTION 225

SOURCE :51\_07.42\_N 051\_07.25.193\_N Latitude  
:01\_41.04\_W 001\_41.02.400\_W Longitude  
30U WB 92100 64517 UTM Coordinate  
422112 136148 BNG Coordinate

LIDAR DLR :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate  
120 Bearing

LIDAR RISO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_40.49\_W 001\_40.29.399\_W Longitude  
30U WB 92731 65140 UTM Coordinate  
422751 136762 BNG Coordinate  
310 Bearing

VIDEO GMGO :51\_07.75\_N 051\_07.44.996\_N Latitude  
:01\_41.02\_W 001\_41.01.200\_W Longitude  
30U WB 92113 65129 UTM Coordinate  
422133 136760 BNG Coordinate

DATA FILES C201549F  
C201554F

==> R264I2 DURATION 18:32 - 19:10 RELEASE HEIGHT 1 M

RUN 20.09.1992 SUNDAY Instantaneous

RELEASE TIME 18:32:00 SMOKE  
18:41:00 SMOKE  
18:49:00 SMOKE  
18:56:00 SMOKE  
19:04:00 SMOKE  
19:10:00 SMOKE

WIND DIRECTION 160

SOURCE :51\_08.54\_N 051\_08.32.402\_N Latitude  
:01\_39.97\_W 001\_39.58.200\_W Longitude  
30U WB 93311 66615 UTM Coordinate  
423350 138229 BNG Coordinate

LIDAR RISO :51\_08.45\_N 051\_08.27.005\_N Latitude  
:01\_39.89\_W 001\_39.53.399\_W Longitude  
30U WB 93407 66450 UTM Coordinate  
423444 138063 BNG Coordinate  
296 Bearing

VIDEO CBDE :51\_08.51\_N 051\_08.30.603\_N Latitude

:01\_39.90\_W 001\_39.53.999\_W Longitude  
30U WB 93393 66561 UTM Coordinate  
423432 138174 BNG Coordinate  
307 Bearing

DATA FILES MAD20J 20-09-92.1 (Bearing 220)  
MAD20K (Bearing 260)  
MAD20L  
MAD20M  
MAD20N  
MAD20O

COMMENTS 18:30 transition from neutral to stable during the instantaneous releases.

WEATHER Trial 7, JD264, 20 Sep had overcast skies producing neutral and stable conditions with SW winds of 5 to 1 m/s resulting in very good mat and modelling and marginal plume and good puff conditions.

==> R265I1 DURATION 13:02 - 14:04 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Instantaneous

RELEASE TIME 13:02:30 SMOKE  
13:22:30 SMOKE SF6  
13:32:40 SMOKE SF6  
13:41:30 SMOKE SF6  
13:51:20 SMOKE SF6  
14:04:30 SMOKE SF6

WIND DIRECTION 070

SOURCE :51\_08.37\_N 051\_08.22.198\_N Latitude  
:01\_39.53\_W 001\_39.31.799\_W Longitude  
30U WB 93829 66309 UTM Coordinate  
423865 137917 BNG Coordinate

LIDAR DLR :51\_08.39\_N 051\_08.23.393\_N Latitude  
:01\_39.88\_W 001\_39.52.800\_W Longitude  
30U WB 93421 66339 UTM Coordinate  
423457 137952 BNG Coordinate  
164 Bearing

LIDAR RISO :51\_08.39\_N 051\_08.23.393\_N Latitude  
:01\_39.88\_W 001\_39.52.800\_W Longitude  
30U WB 93421 66339 UTM Coordinate  
423457 137952 BNG Coordinate  
164 Bearing

VIDEO CBDE :51\_08.40\_N 051\_08.23.997\_N Latitude  
:01\_39.53\_W 001\_39.31.799\_W Longitude  
30U WB 93828 66365 UTM Coordinate  
423865 137972 BNG Coordinate  
150 Bearing

DATA FILES -- 21-09-92.1  
MAD21A C211322P  
MAD21B C211333P  
MAD21C C211341P  
MAD21D  
MAD21E

==> R265C1 DURATION 14:10 - 15:00 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE TIME 14:10:00 - 15:00:00 SMOKE SF6

WIND DIRECTION 120

SOURCE :51\_08.37\_N 051\_08.22.198\_N Latitude  
:01\_39.50\_W 001\_39.29.999\_W Longitude  
30U WB 93864 66310 UTM Coordinate  
423900 137917 BNG Coordinate

LIDAR DLR :51\_08.51\_N 051\_08.30.603\_N Latitude  
:01\_39.82\_W 001\_39.49.200\_W Longitude  
30U WB 93486 66563 UTM Coordinate  
423526 138175 BNG Coordinate  
190 Bearing

LIDAR RISO :51\_08.49\_N 051\_08.29.394\_N Latitude  
:01\_39.75\_W 001\_39.45.000\_W Longitude  
30U WB 93569 66527 UTM Coordinate  
423607 138138 BNG Coordinate

DATA FILES MAD21F 21-09-92.2 C211434F  
C211444F  
C211510F

COMMENTS Good profiles despite smoke into RISO LIDAR generating some bad profiles. Profiles in MAD21F fr 12:42--14:59

==> R265C2 DURATION 15:20 - 16:51 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE TIME 15:20:00 - 16:51:00 SMOKE SF6

WIND DIRECTION 120

SOURCE :51\_08.37\_N 051\_08.22.198\_N Latitude  
:01\_39.50\_W 001\_39.29.999\_W Longitude  
30U WB 93864 66310 UTM Coordinate  
423900 137917 BNG Coordinate

LIDAR DLR :51\_08.52\_N 051\_08.31.193\_N Latitude  
:01\_39.70\_W 001\_39.41.999\_W Longitude  
30U WB 93626 66584 UTM Coordinate  
423665 138193 BNG Coordinate  
190 Bearing

LIDAR RISO :51\_08.52\_N 051\_08.31.193\_N Latitude  
:01\_39.70\_W 001\_39.41.999\_W Longitude  
30U WB 93626 66584 UTM Coordinate  
423665 138193 BNG Coordinate  
203 Bearing

DATA FILES MAD21G 21-09-92.3 C211533F  
MAD21H C211540F  
MAD21I C211552F  
MAD21J C211553F  
C211615F  
C211619F  
C211633F  
C211634F  
C211644F  
C211645F  
C211650F

COMMENTS In profile data file H, I and J smoke into the RISO LIDAR. Profile data follows.

DATA FILES MAD21G during 15:19--15:43  
MAD21H 15:45--16:17  
MAD21I 16:18--16:40  
MAD21J 16:14--16:51

==> R265C3 DURATION 17:30 - 18:16 RELEASE HEIGHT 1 M

RUN 21.09.1992 MONDAY Continuous

RELEASE HEIGHT 1 M

RELEASE TIME 17:19:00 - 18:16:00 SMOKE SF6

WIND DIRECTION 140

SOURCE :51\_08.21\_N 051\_08.12.599\_N Latitude  
:01\_39.47\_W 001\_39.28.200\_W Longitude  
30U WB 93905 66014 UTM Coordinate  
423936 137620 BNG Coordinate

LIDAR DLR :51\_08.37\_N 051\_08.22.198\_N Latitude  
:01\_39.50\_W 001\_39.29.999\_W Longitude  
30U WB 93864 66310 UTM Coordinate  
423900 137917 BNG Coordinate  
220 Bearing

LIDAR RISO :51\_08.41\_N 051\_08.24.602\_N Latitude  
:01\_39.53\_W 001\_39.31.799\_W Longitude  
30U WB 93828 66384 UTM Coordinate  
423865 137991 BNG Coordinate  
243 Bearing

DATA FILES MAD21K 21-09-92.3 C211724F  
C211732F  
C211743F  
C211749F  
C211806F  
C211819F

WEATHER Trial 8, JD265, 21 Sep had overcast skies producing neutral/stable conditions with E winds of 4 to 5 m/s resulting in in very good met and modelling situations and marginal plume and puff concentration conditions.

==> R26611 DURATION 13:41 - 14:29 RELEASE HEIGHT 2.3 M

RUN 22.09.1992 TUESDAY Instantaneous

RELEASE TIME 13:41:25 SMOKE SF6  
13:52:13 SMOKE SF6  
14:07:45 SMOKE SF6  
14:18:35 SMOKE SF6  
14:29:00 SMOKE SF6

WIND DIRECTION 270

SOURCE :51\_08.14\_N 051\_08.08.397\_N Latitude  
:01\_40.31\_W 001\_40.18.599\_W Longitude  
30U WB 92928 65867 UTM Coordinate  
422957 137486 BNG Coordinate

LIDAR DLR :51\_08.14\_N 051\_08.08.397\_N Latitude  
:01\_40.04\_W 001\_40.02.400\_W Longitude  
30U WB 93242 65872 UTM Coordinate  
423272 137488 BNG Coordinate  
200 Bearing

LIDAR RISO :51\_08.13\_N 051\_08.07.806\_N Latitude  
:01\_40.06\_W 001\_40.03.599\_W Longitude  
30U WB 93219 65854 UTM Coordinate  
423249 137469 BNG Coordinate  
235 Bearing

DATA FILES MAD22A 22-09-92.P1 C221341P  
MAD22B C221352P  
MAD22C C221429P  
MAD22D  
MAD22E

==> R2266C1 DURATION 14:45 - 16:15 RELEASE HEIGHT 1 M

RUN 22.09.1992 TUESDAY Continuous

RELEASE TIME 14:45:00 - 16:15:00

WIND DIRECTION 270

SOURCE :51\_08.15\_N 051\_08.09.001\_N Latitude  
:01\_40.32\_W 001\_40.19.199\_W Longitude  
30U WB 92916 65885 UTM Coordinate  
422946 137505 BNG Coordinate

LIDAR DLR :51\_08.14\_N 051\_08.08.397\_N Latitude  
:01\_40.04\_W 001\_40.02.400\_W Longitude  
30U WB 93242 65872 UTM Coordinate  
423272 137488 BNG Coordinate  
200 Bearing

LIDAR RISO :51\_08.13\_N 051\_08.07.806\_N Latitude  
:01\_40.06\_W 001\_40.03.599\_W Longitude  
30U WB 93219 65854 UTM Coordinate  
423249 137469 BNG Coordinate  
235 Bearing

DATA FILES MAD22F 22-09-92.1 C221458F  
C221502F  
C221509F  
C221518F  
C221525F  
C221527F  
C221532F  
C221538F  
C221548F  
C221558F  
C221604F  
C221610F  
C221614F  
C221620F

COMMENTS Very good scanning results from RISO LIDAR. MAD-22F contains scanned profiles fr 14:51--16:31

WEATHER Trial 9, JD266, 22 Sep had overcast skies with occasional rain producing neutral to stable conditions with NW winds of 4 to 1 m/s and "so-so" met and modelling and good concentration

conditions.

==> R26711 DURATION 12:28 - 13:08 RELEASE HEIGHT 2.3 M

RUN 23.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 12:28:00 SMOKE SF6

12:38:30 SMOKE SF6

12:46:30 SMOKE SF6

12:54:00 SMOKE SF6

13:08:30 SMOKE SF6

WIND DIRECTION 260

SOURCE :51\_08.14\_N 051\_08.08.397\_N Latitude  
:01\_40.31\_W 001\_40.18.599\_W Longitude  
30U WB 92928 65867 UTM Coordinate  
422957 137486 BNG Coordinate

LIDAR DLR :51\_08.09\_N 051\_08.05.403\_N Latitude  
:01\_40.01\_W 001\_40.00.599\_W Longitude  
30U WB 93279 65780 UTM Coordinate  
423308 137395 BNG Coordinate  
315 Bearing

LIDAR RISO :51\_08.10\_N 051\_08.05.993\_N Latitude  
:01\_40.00\_W 001\_40.00.000\_W Longitude  
30U WB 93290 65799 UTM Coordinate  
423319 137414 BNG Coordinate  
349 Bearing

DATA FILES -- 23-09-92.1  
MAD23B  
MAD23C C231246P  
MAD23D  
MAD23E C231308P

COMMENTS RISO LIDAR poor profiles due to smoke into the instrument

==> R267C1 DURATION 13:25 - 17:28 RELEASE HEIGHT 1 M

RUN 23.09.1992 WEDNESDAY Continuous

RELEASE TIME 13:25:00 - 17:28:00 SMOKE SF6

WIND DIRECTION 260

SOURCE :51\_08.17\_N 051\_08.10.196\_N Latitude  
:01\_40.30\_W 001\_40.17.999\_W Longitude  
30U WB 92938 65922 UTM Coordinate  
422969 137542 BNG Coordinate

LIDAR DLR :51\_08.09\_N 051\_08.05.403\_N Latitude  
:01\_40.01\_W 001\_40.00.599\_W Longitude  
30U WB 93279 65780 UTM Coordinate  
423308 137395 BNG Coordinate  
315 Bearing

LIDAR RISO :51\_08.10\_N 051\_08.05.993\_N Latitude  
:01\_40.00\_W 001\_40.00.000\_W Longitude  
30U WB 93290 65799 UTM Coordinate  
423319 137414 BNG Coordinate  
349 Bearing

DATA FILES 23-09-92.2 C231329F  
MAD23F C231335F  
C231342F  
C231342F  
C231359F  
C231413F  
C231420F  
C231428F  
23-09-92.3 C231434F  
C231444F  
C231453F  
C231458F  
MAD23G C231505F  
C231510F  
C231517F  
23-09-92.4 C231523F  
C231526F  
C231535F  
C231542F  
C231551F  
C231556F  
C231603F  
C231621F

23-09-92.5 C231623F

C231627F

C231635F

C231640F

C231651F

C231655F

C231704F

C231719F

C231722F

COMMENTS RISO LIDAR scanning -2--10 deg. Profiles in MAD23F fr

13:32--14:46 and MAD23G 15:00--17:31

==> R23102 DURATION 17:36 - 18:01 RELEASE HEIGHT 2.3

RUN 23.09.1992 WEDNESDAY Instantaneous

RELEASE TIME 17:36:30 SMOKE SF6

17:47:30 SMOKE SF6

18:01:00 SMOKE

WIND DIRECTION 260

SOURCE :51\_08.14\_N 051\_08.08.397\_N Latitude  
:01\_40.31\_W 001\_40.18.599\_W Longitude  
30U WB 92928 65867 UTM Coordinate  
422957 137486 BNG Coordinate

LIDAR DLR :51\_08.09\_N 051\_08.05.403\_N Latitude  
:01\_40.01\_W 001\_40.00.599\_W Longitude  
30U WB 93279 65780 UTM Coordinate  
423308 137395 BNG Coordinate  
315 Bearing

LIDAR RISO :51\_08.10\_N 051\_08.05.993\_N Latitude  
:01\_40.00\_W 001\_40.00.000\_W Longitude  
30U WB 93290 65799 UTM Coordinate  
423319 137414 BNG Coordinate  
349 Bearing

VIDEO GMGO [positioned near by source ?]

DATA FILES MAD23H 23-09-92.6 C231733F  
MAD23I 23-09-92.7 C231738F  
--

COMMENTS 18:01 SIX GRAND PUFFS WITH 20 SECONDS IN BETWEEN: MADONA GRAND FINAL!

WEATHER Trial 10. JD267, 23 Sep had mostly cloudy skies producing neutral and stable conditions with SW winds of 6 to 8 m/s resulting in good met and modelling and good concentration conditions.

THE MADONA CDROM DATA BASE (VERS 1.01) IS AVAILABLE FROM:

Timothy J. Higgs at CBDE Porton Down, UK  
+44-(0)980-613311 fax  
email: 100071.2321@compuserve.com

# Appendix V

## MADONA: DIFFUSION MEASUREMENTS OF SMOKE PLUMES AND OF SMOKE PUFFS

Torben Mikkelsen and Hans E. Jørgensen  
Department of Meteorology and Wind Energy  
Risø National Laboratory, DK-4000 Roskilde, Denmark

Kenneth Nyrén  
FOA Department of NBC Defense  
National Defense Research Establishment  
S-901 82 Umeå, Sweden

Jürgen Streicher  
DLR-Department of Optoelectronics  
D-8031 Oberpfaffenhofen, Germany

### 1. INTRODUCTION

To accomplish the objective of obtaining a high resolution diffusion data base, the MADONA trials made use of smoke,  $\text{SF}_6$  and propylene tracer gases in the dispersion experiments that took place in the terrain influenced wind and turbulence fields over the Porton Down test site.

A total of 27 diffusion experiments were conducted during the days of September 14 to 23 during unstable, neutral and stable atmospheric conditions at downwind distances between 100 and 1000 m from the release point. In total, some 84 instantaneous releases of smoke puffs and 8 continuous hour long lasting combined  $\text{SF}_6$  and smoke plume releases were successfully obtained. This paper describes the dispersion characteristics obtained from the MADONA trials based on the smoke puffs and plume experiments conducted:

Puffs and plumes were generated by mixing liquid  $\text{SiCl}_4$  (Silicon-tetrachloride) and a 25% solution of  $\text{NH}_4\text{OH}$  (Ammonia) in their proper stoichiometric ratio. Puffs were generated by firing of a two-component cylindrical charge (100 ml of  $\text{SiCl}_4$  and 320 ml of  $\text{NH}_4\text{OH}$ ) with a burster tube filled with plastic explosive. Continuous smoke plumes were generated by mixing the same chemicals into a strong air-jet from two constant flow rate pumps. Depending on the flow rates and the stability of the atmosphere, the puffs and plumes could be made visible kilometers downwind.

Detection of the time and space dependent dispersion were based on two aerosol LIDAR remote sensing systems, one visio-ceilometer (also lidar-based) and one mobile  $\text{SF}_6$  real-time flame photometer. The LIDAR systems were positioned at various downwind positions to measure the aerosol backscatter coefficients (air concentration) at lines of sight normal to the smoke and puff centerline travel. While the visio-

ceilometer

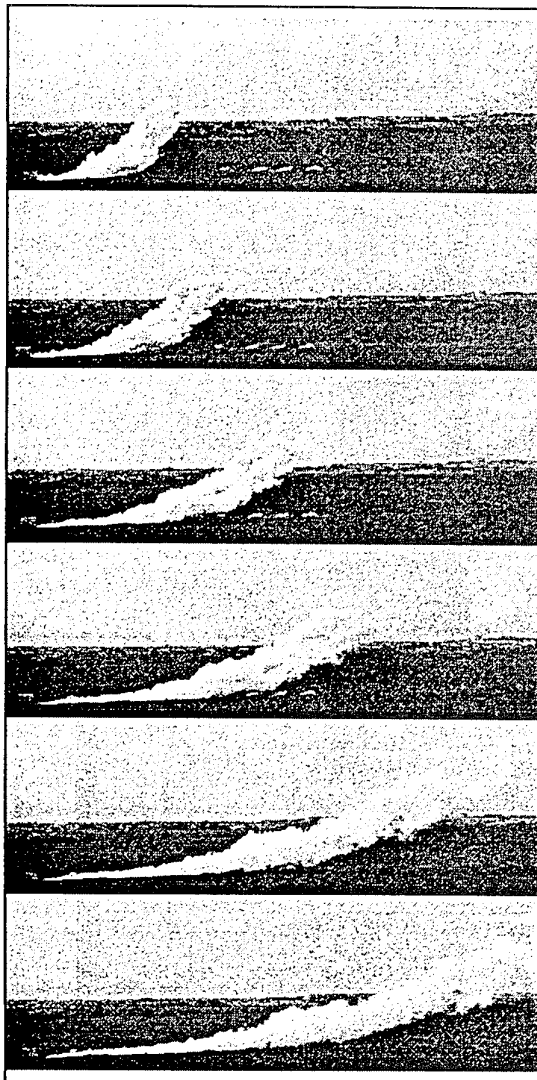


Figure 1. Ground-level instantaneous puff release during stable stratification exhibiting vertical shear.

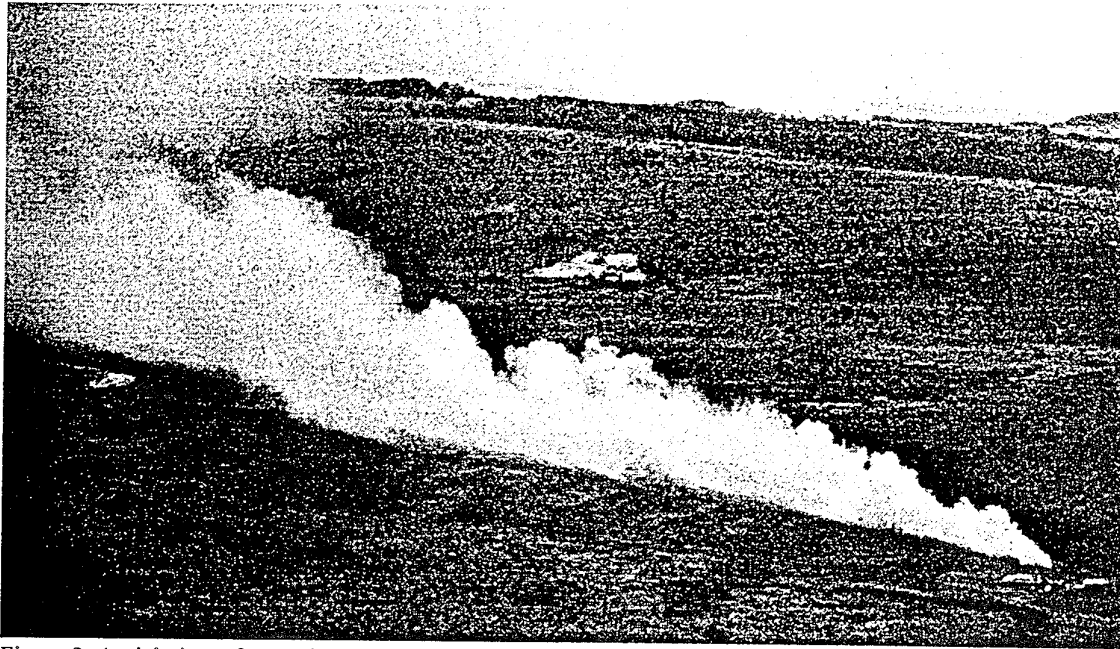


Figure 2. Aerial view of a continuous smoke plume traversing the Porton Down Bowl area.

always measured the smoke concentrations near the ground, the mini-LIDAR system were optionally operated to scan the vertical concentration profiles. The Risø Mini-LIDAR system is operating with an effective range resolutions of 1.5 meter and a time resolution of 1/3 Hz. It was in operation during all of the MADONA puff and plume dispersion experiments. Further description of the lidar systems are presented in Jørgensen et al. Ibid.

In this paper, we will first show some diffusion results obtained during the continuous release experiment MAD 18A, which took place in the Bowl area of the Porton Down terrain on Sep. 18 between 17:42 and 18:42 during approximately 4 m/s wind speed and during near-neutral near neutral conditions. The corresponding mean and turbulence quantities measured by one of the Risø's teams sonic anemometers is presented in an accompanying paper (Mikkelsen and Jørgensen (1995).

Secondly, we will show some diffusion measurements from an instantaneously released puff (MAD 23 H) measured during stable conditions.

#### CONTINUOUS SMOKE PLUME EXPERIMENT

Figure 2 shows an aerial view of the continuous smoke release which was used in the one-hour long lasting continuous plume experiment MAD 18 A. The mini-LIDAR system was located 550 m down wind of the source and positioned 250 m cross wind from the plume centerline.

The mini-lidar was operated to produce two-dimensional mean concentration isoplethes in a "cross wind-height plane" perpendicular to the mean wind direction. The measured 1-hour mean concentration is shown in Fig. 3. The isoplethes are normalized relative to the maximum concentration at the ground.

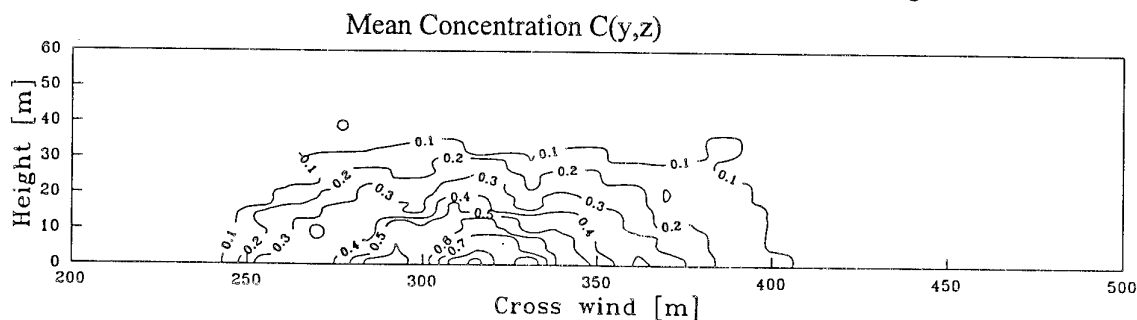


Figure 3. Mean concentration isoplethes from MAD 18 A measured by the Risø mini-lidar system.

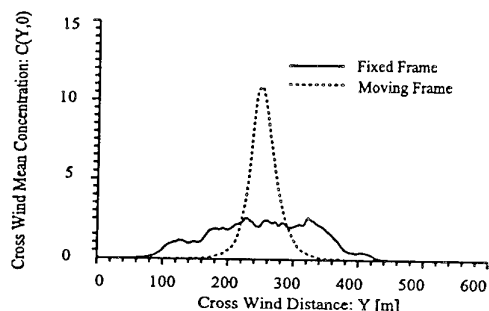


Figure 4. Measured cross wind mean concentrations profiles at ground level during MAD 18 A.

The measured mean concentrations at ground level (measured by the lidar beam at approximately 1 meters height above the ground in order to avoid ground clutter) is presented in Fig.4. These measurements are based on the lidar scans taken at the lowest azimuth angle (zero degrees).

Two sets of concentration profiles are presented, a *fixed frame* concentration profile and a *moving frame* concentration profile:

The *fixed frame* curve represents the 1-hour averaged concentration distribution, corresponding to the isopleth at ground level ( $z = 0$ ) in Figure 3. This curve includes the spread resulting from plume meander during the measurement period (1-hour). Its corresponding  $\Sigma$ -value is 68 meters.

The *moving frame* mean concentration profile has been obtained by ensemble averaging the instantaneous concentration profiles obtained by the lidar system:

The individual concentration profiles (of which some 1200 is obtainable during one hour sampling of the smoke plume with a 1/3 Hz sampling rate) were first superpositioned with respect to their individual center of mass, and then ensemble averaged.

The *moving frame* concentration profile in Figure 4 therefore represents the ensemble averaged instantaneous spread, or the plume diffusion without the meander contribution. The *moving frame* spread ( $\sigma_{puff} = 28$  meters) is therefore a measure for the relative diffusion (at the 550 m distance) in this experiment.

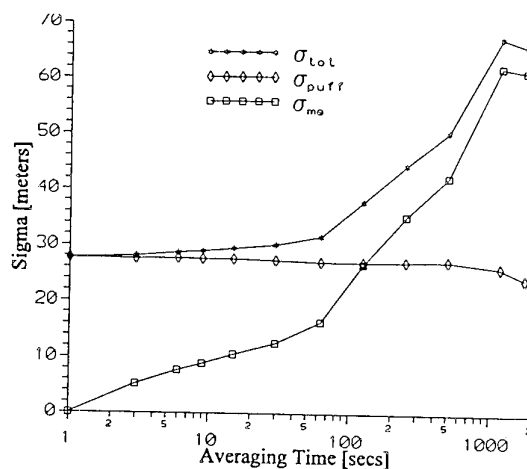


Figure 5. The plume spread in experiment MAD 18 A as function of averaging time.

#### Legend.

$\sigma_{puff}$ : Running-mean averaged instantaneous spread.

$\sigma_{me}$ : Running-mean averaged meander contribution from center of mass movement.

$\sigma_{tot}$ : Total plume spread calculated from:

$$\sigma_{tot}^2 = \sigma_{puff}^2 + \sigma_{me}^2$$

The MAD 18 A data set also enables a study of the plume spread averaging-time dependency in this experiment, see Figure 5. Beginning with the instantaneous value  $\sigma_{puff} = 28$  meters (corresponding to zero averaging time) the measured plume width increases with averaging time and reaches 68 m (standard deviation) after one hour of continuous sampling. This increase with averaging time is due to the meandering of the smoke plume. The stagnation and slight decrease in  $\sigma_{puff}$  at averaging times longer than 1000 s is due to a decrease in the turbulence level and approaching stable conditions towards the end of the experiment.

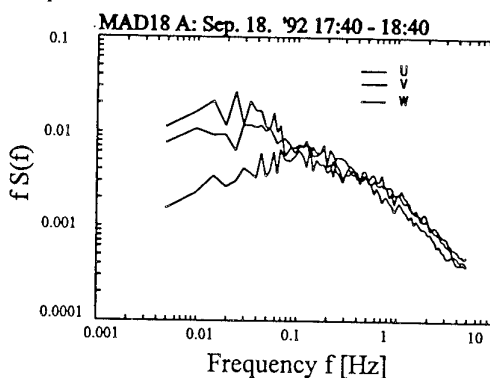


Figure 6. Measured spectra during MAD 18 A.

## INSTANTANEOUS SMOKE PUFF EXPERIMENT

Also the instantaneous smoke puff experiments were detected by lidar.

Puffs were generated by the Swedish participants by firing of a two component cylindrical charge (containing 100 ml of  $\text{SiCl}_4$  and 320 ml of  $\text{NH}_4\text{OH}$ ) with a burster tube filled with plastic explosive.

Figure 7 shows the firing of Puff No. MAD 23 H (elevated release). The explosion results in an instant smoke puff of initial and often symmetric size  $\sigma_{\text{puff}}(0)$  of the order of 2-3 meters.

Puffs were sometimes additionally accompanied by a small balloon containing measured amounts of  $\text{SF}_6$  and were in addition to the lidar detection systems also measured by a mobile  $\text{SF}_6$  flame detector system operated by the Germans.

Puff MAD 23 H was released in the evening on Sep. 23 during low wind speeds (2 m/s at 7 meters height) and strong stable conditions ( $z/L \approx 1$ ) as can be seen from the sonic measurements (Mikkelsen and Jørgensen (1995)).

Figure 8 shows the 1/3 Hz lidar-measured cross section concentration profiles at ground level some 100 meters downwind from the release point. First follows the bulk part of the puff, then follows a long (10-min long lasting) tail that sticks to the ground, see also Figure 1. Meandering is here seen to be suppressed.

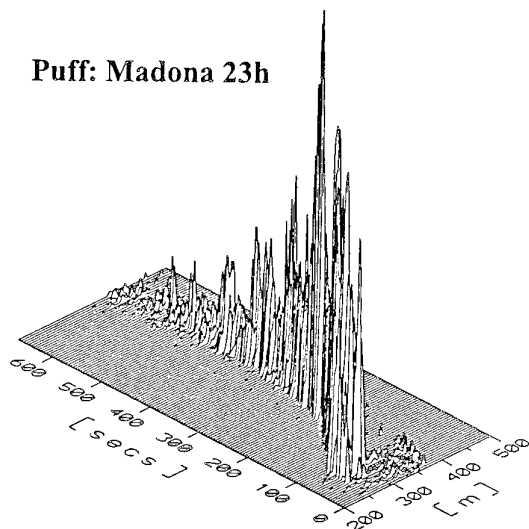


Figure 8. Lidar cross-sections at ground level from the instant smoke puff release MAD 23 H ( $z/L \approx 1$ ).

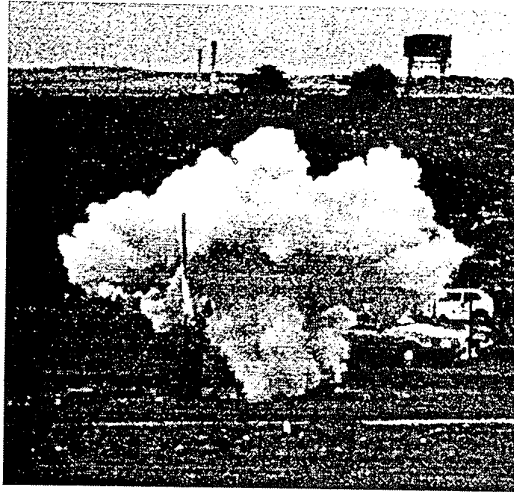


Figure 7. Instantaneous smoke puff detached from the source point (ground level view).

## Acknowledgements

Part of this work (contributions by Risø National Laboratory and DLR) has been sponsored by the Commission of the European Union (EU-DGXII Radiation Protection Research Program, under contract No. FI3P-CT92-0044, "RODOS").

Risø's participation in the MADONA trials was made possible by a travel grant by U.S. Army Research Development & Standardization Group-UK, under contract No. DAJA45-92-M-0344.

## References

- Cionco R.M., W. aufm Kampe, C. Biltoft, J.H. Byers, C.G. Collins, T.J. Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, D.J. Ride, R. Robson, J.M. Santabarbara, J. Streicher, S. Thykier-Nielsen, H. van Raden, H. Weber (1995): An overview of MADONA: A multi-national field study of high-resolution meteorology and diffusion over complex. Submitted to: *Bulletin of the American meteorological Society*.
- Jørgensen, H.E., T. Mikkelsen, D. J. Ride, T. Higgs, C. J., W. aufm Kampe, H. Weber, K. Nyrén and P.E. Johansson (1995): MADONA: Concentration fluctuation analysis. *Ibid*.
- Jørgensen, H.E. and T. Mikkelsen (1993). Lidar measurements of plume statistics. *Boundary-Layer-Meteorol.* **62**, pp. 361-378.
- Mikkelsen, T. and H.E. Jørgensen (1995) MADONA: On-site real-time turbulence measurements. *Ibid*.

# MADONA: ON-SITE REAL-TIME TURBULENCE MEASUREMENTS

Torben Mikkelsen and Hans E. Jørgensen  
Department of Meteorology and Wind Energy  
Risø National Laboratory, DK-4000 Roskilde, Denmark

## 1. INTRODUCTION

Two sonic anemometers/thermometers (Kaijo Denki DAT300), displaced by 100 meters and mounted on 7-meter tall met-towers, were operated by the Danish team during the Porton Down MADONA trials.

On-line data processing and quality assurance of the Danish-teams wind and temperature measurements formed the basis for real-time state and stability characterization of the turbulent surface layer over the field trial terrain. Running continuously during the entire experimental campaign September 14 to 23 1992, the sonic data provided real-time surface layer turbulence statistics of the most important scaling parameters for the in-situ dispersion assessments and modelling, including:

1. Mean Wind speed, Direction, Turbulent Kinetic Energy, Shear Stress, Sensible Heatflux, Monin-Obukhov Stability parameters and Temperature statistics.
2. Time series plots of high-resolution (10 Hz) wind and temperature signals.
3. Time series of short-time averaged (1-min running mean) quantities of wind speed, direction, turbulence level, shear stress and heat flux.
4. Spectral analysis of the three wind ( $u', v', w'$ ) and temperature ( $T'$ ) signals.

This information is now available during the MADONA analysis and model evaluation phase. The mean and turbulence data have in particular proven useful for:

- Insight in fine scale temporal evaluation of the boundary flow and turbulence over the Porton Down terrain during each diffusion test.
- Information about the spatial in-homogeneity of the turbulence over Porton Down.

- Insight in the turbulent scales and their importance for the exchange and diffusion processes.
- Detailed turbulence measurements near the source point for use in the model simulation of the experiments.

## EXAMPLES OF DATA OBTAINED

*MAD18: Sep. 18., see next page:*

Mean and turbulence measurements obtained from Sonic 1. The vertical lines and bars indicate the start, occurrence, and stop of puff and plume release periods.

*MAD23: Sep. 23., see last two pages:*

Mean and turbulence data obtained on Sep 23 from sonic1 and sonic 2, both located in the Porton Down Bowl area and separated by 160 meters.

Although the terrain is non-homogeneous and therefore varies somehow between the two sonic sites, the obtained (10 min averaged) statistics is remarkable identical at sonic site 1 and sonic site 2.

## Acknowledgements

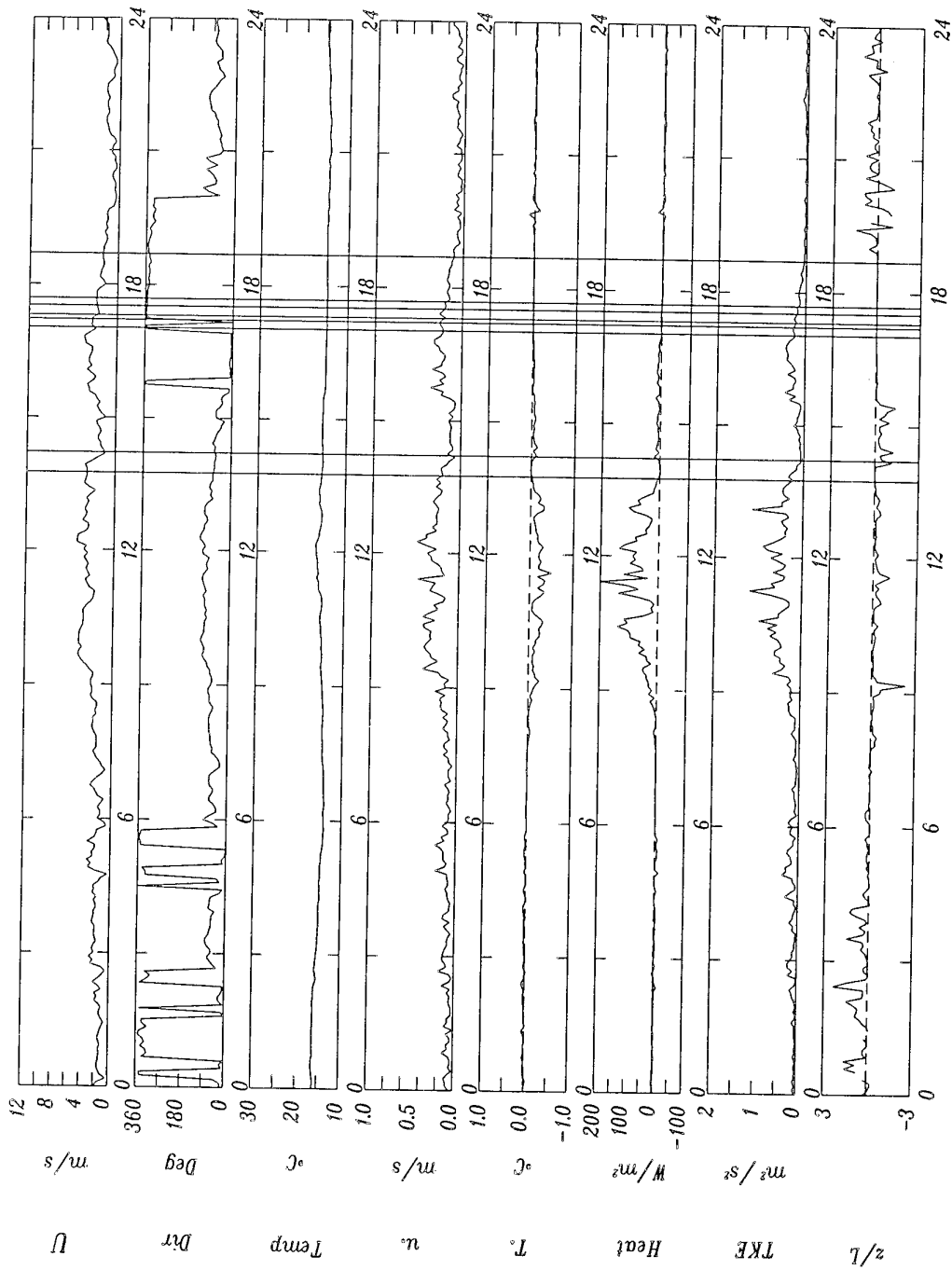
Part of this work (contribution by the Risø National Laboratory) has been sponsored by the EU DGXII Radiation Protection Program "RODOS", under contract No. FI3P-CT92-0044).

Risø's participation in the MADONA trials was made possible by a travel grant by U.S. Army Research Development & Standardization Group-UK, under contract No.DAJA45-92-M-0344.

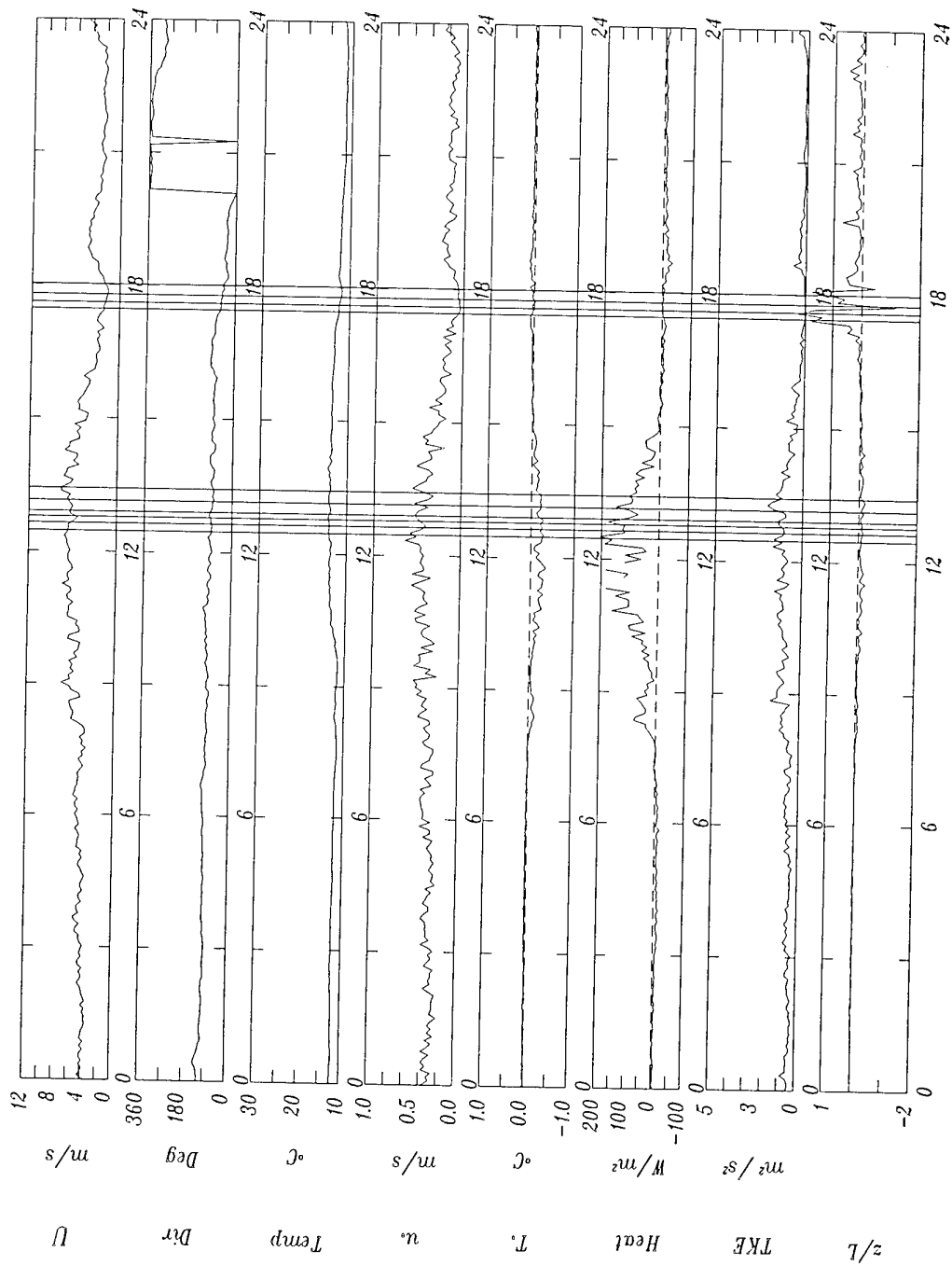
## References

Cionco R.M., W. aufm Kampe, C.Biltoft, J.H.Byers, C.G.Collins, T.J.Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, D.J. Ride, R.Robson, J.M. Santabarbara, J. Streicher, S. Thykier-Nielsen, H. van Raden, H. Weber (1995): An overview of MADONA: A multi-national field study of high-resolution meteorology and diffusion over complex. Submitted to: *Bulletin of the American meteorological Society*.

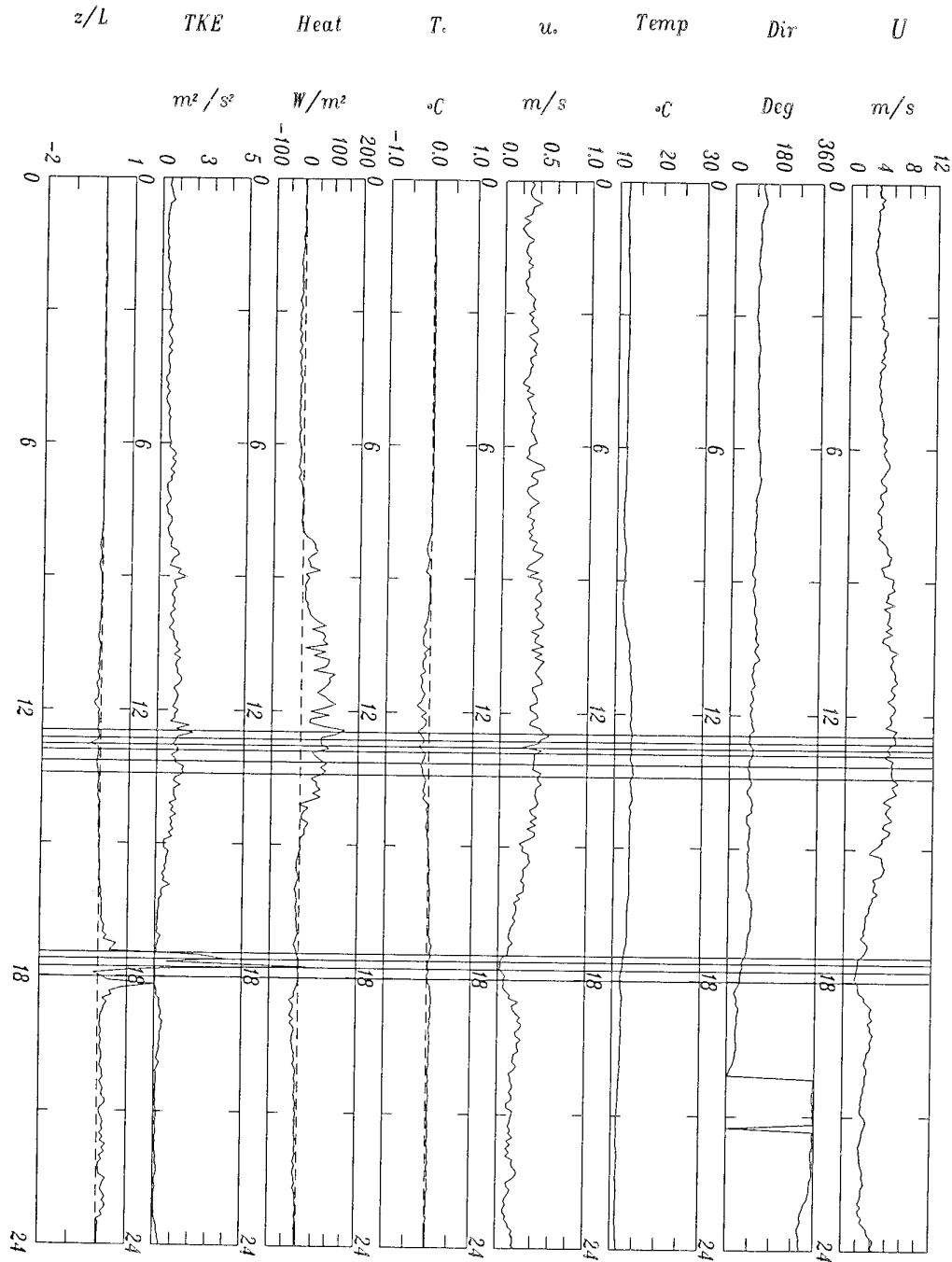
Sonic 1 micromet: 920918 MADONA



Sonic 1 micromet. 920923 MADONA



# Sonic 2 micromet. 920923 MADONA



MADONA:  
REAL-TIME DIFFUSION MODEL SIMULATIONS

S. Thykier-Nielsen, T. Mikkelsen and J. Santabarbara  
Department of Meteorology and Wind Energy  
Risø National Laboratory, DK-4000 Roskilde, Denmark

D. J. Ride and T. Higgs  
Assessment and Modelling Division  
CBDE, Porton Down, Salisbury, Wilts SP4 0JQ, England

H. Weber  
German Military Geophysical Office  
Mont Royal, D-5580 Traben-Trarbach, Germany

## 1. INTRODUCTION

Simulations of the airflow and diffusion over the MADONA topography are now being made with a variety of models. Several simulations were made on-site and in real-time, while others were made after the experiment during the analyses of the observed wind and diffusion pattern. Wind fields and wind-related parameters were simulated with high resolution wind models such as HRW (Cionco, 1985), Ball and Johnson (Ball and Johnson, 1974, and Weber and aufm Kampe, 1992) and LINCOM.

This paper describes the simulation of diffusion of smoke and tracer gas during two of the MADONA experiments using the local-scale real-time dispersion modeling system LINCOM/RIMPUFF.

## 2. THE LINCOM/RIMPUFF DISPERSION MODEL

### 2.1 *Flow model LINCOM:*

LINCOM (Troen and de Baas, 1986; Walmsley et al. 1990; Santabarbara et al. 1993) is an extremely fast diagnostic, non-hydrostatic dynamic flow model based on the solution of linearized versions of the three momentum equations and the continuity equation with a first order spectral turbulent diffusion closure besides.

Its truncated physics (linearization, neutral stratification) restricts it from application to severe non-uniform terrain, but considerable realism in the resulting wind fields can be achieved by use of assimilation techniques to match the models resulting windfield to locally measured tower or forecast winds, as this paper will show.

Stratification effects are in LINCOM accounts for only by matching (based on least square error) the resulting flow field to the available observations. For near-neutral stability conditions, however, the flow model accounts for many terrain features with only modest mathematical and computational effort. LINCOM runs extremely fast in "fitting" mode (100 by 100 grid points are processed in less than 1 second on a 50 MHz 486 DX PC).

A thermodynamic energy balance, based on an estimated or measured temperature field, is presently under development (version: LINCOM-T) (Moreno et.al., 1994) by which stratified flow effects, such as valley and local cold air drainage jets, in principal can be modeled. But even so equipped, this model is not an alternative to a full prognostic, primitive-equation based non-hydro-static flow model that accounts for differential heating (sea-breeze, valley slope and drainage winds etc.).

However, by responding in seconds on a standard PC, LINCOM is an attractive "driver" for fast real-time atmospheric dispersion models such as the puff model RIMPUFF in assessment of emergency response and decision support.

### 2.2 *Diffusion model RIMPUFF:*

RIMPUFF (Mikkelsen et al., 1984; Thykier-Nielsen et al., 1989; Thykier-Nielsen and Mikkelsen, 1993) is a fast and operational puff diffusion code that is suitable for real-time simulation of puff and plume dispersion during time and space changing meteorology. Also optimized for fast response on a PC this model is provided with a puff splitting feature to deal with plume bifurcation and flow divergence due to channeling, slope flow and inversion effects in non-

uniform terrain.

For real-time applications, RIMPUFF can be driven by wind data from combinations of:

- 1) A permanent network of meteorological towers,
- 2) The flow model LINCOM (or similar), and
- 3) On-line Numerical Weather Forecast data.

The puff or plume diffusion processes are in RIMPUFF controlled by local turbulence levels, either provided directly from on-site measurements, or provided via pre-processor calculations (Mikkelsen and Desiato, 1993). RIMPUFF is further equipped with standard plume rise formulas, inversion and ground level reflections, gamma dose algorithms and wet/dry depletion.

### 2.3 Evaluation record:

Concurrently with the improvements in code, the LINCOM/RIMPUFF modeling system is continuously being evaluated using full scale experimental data. For non-homogeneous terrain applications, recent references include: Thykier-Nielsen et al. (1989); Massmeyer et al. (1990); Thykier-Nielsen et al. (1990a); Kamada et al. (1991); Thykier-Nielsen et al. (1991); Kamada et al. (1992); Thykier-Nielsen et al. (1993a).

## 3 SIMULATION OF A MADONA EXPERIMENT

The RIMPUFF code (Thykier-Nielsen, 1993) was used in real-time to calculate transport and diffusion of smoke and gas tracer aerosols in the wind fields calculated by LINCOM and assimilated to the on-site continuously operated 15 meteorological stations.

### 3.1 LINCOM data assimilation procedure

Wind fields calculated by LINCOM reflect the terrain-perturbed response to a single upwind "free" or terrain unperturbed input wind. That is, the input wind is the mean speed and direction that would prevail uniformly over the entire model domain in the absence of hills or mountains.

However, the tower observations over the Porton terrain are not "free winds", but are to the contrary influenced by their nearby surrounding topography.

The question therefore arises on how to use terrain-influenced observations for driving a diagnostic Navier-Stoke Eqs. based flow model:

In this particular case, because LINCOM is based

on linearized equation, the response from two orthogonal inputs (East and North, say) results in two orthogonal perturbation fields.

The following procedure can consequently be adapted to obtain model windfields that assimilate observations obtained within the terrain best possible:

- 1 First calculate the terrain-induced perturbations over the entire modeling domain from two unit-amplitude "East" and "North" free winds. This (most time-consuming part) is only done once.
2. Backfit, by using a linear-combination of the perturbations obtained in step 1, the free wind vector that best possible fits (by least-square-error method) the available met-tower observations. (For cases where a single met-tower is used, this can be done exactly).
3. By use of the "best-fitted" free wind vector obtained during step 2 finally calculate the wind field at the actual positions and heights where puffs are being advected.

Further details are listed in Thykier-Nielsen et al.(1993a).

### 3.2 Model Simulation

To date, two experiments have been simulated by LINCOM/RIMPUFF. Those are the experiments of September 17 and 22. In both cases "fitted" LINCOM windfields were used and updated every 5 minutes with the observed wind speed and direction measured at the 15 meteorological stations. The simulations covered a release period of up to 6 hours. The resulting flow and concentration fields are shown on figure 1 to 3.

In a study made by Burman (1994), LINCOM was evaluated using data from one of the Porton trials. Measured wind-speeds and -directions at 9 different locations were compared to those predicted by LINCOM. In general there is a good agreement between measured and predicted values. However some differences are seen where the roughness length differs significantly from the averaged roughness length assumed by LINCOM. Further the study shows the importance of carefully choosing the meteorological stations used in the assimilation procedure (see also: Thykier-Nielsen et.al., 1993a). Only the meteorological stations inside the area where the puffs and plumes were dispersed should be used in the assimilation of observations to the LINCOM calculations.

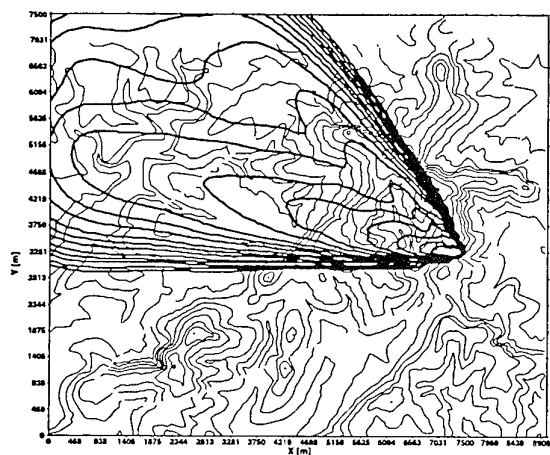


Figure 1. Simulation of an experiment on September 17., 1992: Contours are integrated air concentration calculated by RIMPUFF 5 hours after start of release.

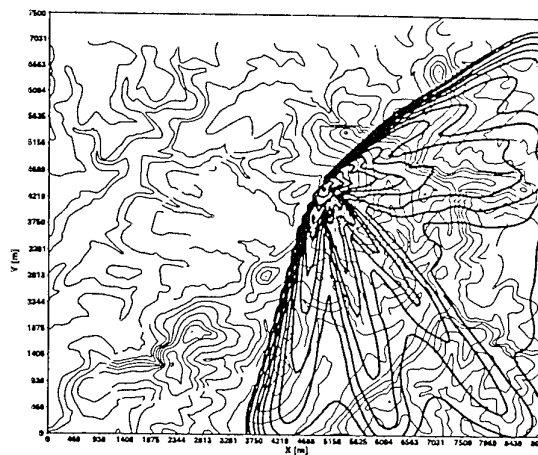


Figure 3. Simulation of the experiment on September 22., 1992: Contours are integrated air concentration at 17:00 hrs, 6 hours after start of release.

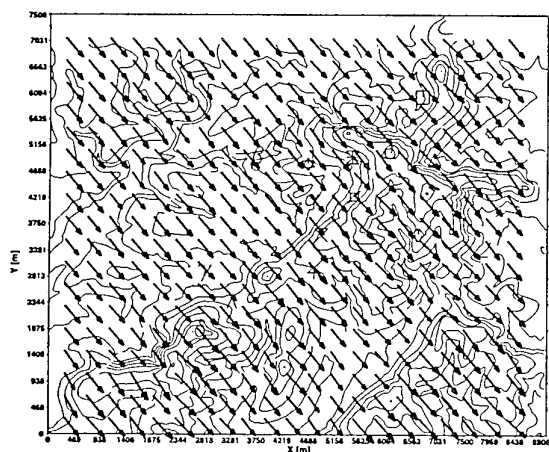


Figure 2. Simulation of the experiment on September 22., 1992: LINCOM windfield fitted to the observations at the 9 meteorological stations inside the model domain. Time: 14:00 hrs, 3 hours after start of release.

#### 4 ACKNOWLEDGEMENTS

George Lai, NASA Goddard Space Flight Center, USA is gracefully acknowledged for invention on the tower assimilation method used in LINCOM.

The modeling part of this work has been sponsored by the EU DG-XII Radiation Protection Research Programme, under contracts No. FI3P-CT92-0044 (RODOS).

## REFERENCES

- Ball, J., and S. Johnson (1978). Physically-based High-Resolution Surface Wind and Temperature Analysis for EPAMS, Report ASL-CR-78-0048-1, USA Atmospheric Sciences Laboratory (contact R. Cionco), WSMR, NM, USA.
- Burman, J. (1994). Vinddiagnosmodell byggd kring LINCOM. Report FOA-D-94-00025-4.5-SE, Swedish National Defence Research Establishment (FOA). (*In Swedish. English title: Diagnostic wind model based on LINCOM*)
- Cionco, R. M. (1985). Modeling Wind Flow and Surface Layer Profiles over Complex Terrain and Within Vegetative Canopies, Forest-Atmosphere Interactions, Editors: B. A. Hutchison and B. B. Hicks, D. Reidel Publishing Co., The Netherlands.
- Kamada, R.F., S.A. Drake, T. Mikkelsen and S. Thykier-Nielsen (1991). A Comparison of eight cases from the Vandenberg AFB MT. Iron tracer study with results from the LINCOM/RIMPUFF Dispersion Model. Naval Postgraduate School, Monterey, California, NPS report No.: NPS-PH-92-006. Dec 1991.
- Kamada, R.F., S.A. Drake, T. Mikkelsen and S. Thykier-Nielsen (1992). LINCOM/RIMPUFF vs. Mt. Iron, a data/modelling comparison. Proceedings of the 7th JAN-NEF Envir. Safety & Protection Subcomm. Meet. Aug 10-14, 1992, NPS, Monterey, CA.
- Massmeyer, K., K. Born, B. Erbhäusser, C. Hauk, Th. Flassak (1990). Regional flow fields in North Rhine Westfalia - A Case study comparing flow models of different complexity. 18th ITM on Air Pollution Modelling and its Applications, NATO-CCMS, Vancouver, Canada.
- Mikkelsen, T., S.E. Larsen and S. Thykier-Nielsen (1984). Description of the Risø Puff Diffusion Model. Nuclear Technology, Vol. 67, pp. 56-65.
- Mikkelsen, T. (1992) Atmospheric dispersion models for real-time application in the decision support system being developed within the CEC. In: Olesen, H.R. and T. Mikkelsen (Eds.) 1992: Proceedings of the workshop "Objectives for Next Generation of Practical Short-Range Atmospheric Dispersion Models", Risø, Denmark, May 6-8 Danish Center for Atmospheric Research (DCAR), P.O. Box 358, DK-4000 Roskilde. pp 109-130.
- Mikkelsen, T. and F. Desiato (1993): Atmospheric Dispersion Models and Pre-processing of Meteorological Data for Real-time Application. In: Proceedings of the Third International Workshop on Real-time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, Schloss Elmau, Bavaria, October 25-30 1992. To appear in: Journal of Radiation Protection Dosimetry (Dec. 1993).
- Moreno, J., A.M. Sempreviva, T. Mikkelsen, G. Lai and R. Kamada (1994). A spectral diagnostic model for wind flow simulation: extension to thermal forcing. In Air Pollution II Volume 1: Computer Simulation. Proceedings of the Second International Air Pollution Conference, September 27-29, 1994, Barcelona, Spain.
- Computational Mechanics Publications, pp 31-38.
- Olesen, H.R. and T. Mikkelsen (Eds.) 1992: Proceedings of the workshop "Objectives for Next Generation of Practical Short-Range Atmospheric Dispersion Models", Risø, Denmark, May 6-8 Danish Center for Atmospheric Research (DCAR), P.O. Box 358, DK-4000 Roskilde. 262 pp.
- Santabàrbara, J.S., T. Mikkelsen, R. Kamada, G. Lai and A.M. Sempreviva (1993): LINCOM Wind Flow Model, Risø-R-report(EN), 37 pp. Available on request from: Department of Meteorology and Wind Energy, Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark.
- Thykier-Nielsen, T. Mikkelsen, S.E. Larsen, I. Troen, A.F. de Baas, R. Kamada, C. Skupniewicz and G. Schacher. (1989) A model for accidental releases in complex terrain. In: Air Pollution Modelling and its Application VII (Ed. H. van Dop) Plenum Publ. Corporation) pp 65-76.
- Thykier-Nielsen, S., T. Mikkelsen, R. Kamada and S.A. Drake (1990a): Wind Flow Model Evaluation Study for Complex Terrain. In: Proceedings from the ninth Symposium on Turbulence and Diffusion. American Meteorological Society. Risø, Denmark, April 30 - May 3. 1990. pp 421-424.
- Thykier-Nielsen, S., T. Mikkelsen and V. Herrnberger (1991): Real-time Wind and Dispersion Simulation of tracer experiments conducted over complex terrain during weak and neutral flow conditions. In proceedings of: OECD/NEADB Specialists' meeting on Advanced Modelling and Computer Codes for Calculating Local Scale and Meso-Scale Atmospheric Dispersion of Radionuclides and their Applications (AD-LMS'91), 6-8 March 1991, OECD NEA Data Bank, Saclay, France. pp. 86-119 (OECD PUBLICATION No. 75907 1991).
- Thykier-Nielsen, S., J.M. Santabàrbara and T. Mikkelsen (1993a). A real-time dispersion scenario over complex terrain. In: Proceedings of the 3. International Workshop on Real-time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation. Schloss Elmau, Bavaria, Oct 25-30, 1992. Accepted for publication in: Radiation Protection Dosimetry, Nov. 1993.
- Thykier-Nielsen, S. and T. Mikkelsen (1993b): **RIMPUFF USER'S GUIDE** (Version 33 - PC version). Available on request from: Department of Meteorology and Wind Energy, Risø National Laboratory, P.O. BOX 49, DK 4000 Roskilde.
- Thykier-Nielsen, S., Mikkelsen T. and Moreno, J. (1993). Experimental evaluation of a pc-based real-time dispersion modeling system for accidental releases in complex terrain. Proceedings from 20th International Technical Meeting on Air Pollution Modelling and its Application, Valencia, Spain, November 29 - December 3., 1993.
- Troen I. and de Baas, A.F., 1986: A spectral diagnostic model for wind flow simulation in complex terrain, Proc. Euro. Wind Energy Assoc. Conf., Rome, Oct. 7-9, 1986.
- Walmsley, J.L., I. Troen, D.P. Lalas and P. J. Mason (1990):

Surface-layer Flow in Complex terrain: Comparison of Models and Full-scale Observations. Boundary layer Meteorology Vol. 52, pp 259-281.

Weber, H. and W. aufm Kampe (1992). Das Programmsystem "HEARTS" (Hazard Estimation after Accidental Release of Toxic Substances), Annalen der Meteorologie 27, Deutsche Meteorologen-Tagung 1992, Selbstverlag des Deutschen Wetterdienstes, ISSN 0072-4122, Offenbach am Main, Germany.

# MADONA: CONCENTRATION FLUCTUATION ANALYSIS

Hans E. Jørgensen \*and Torben Mikkelsen

Risø National Laboratory  
Roskilde, Denmark

Welfhart aufmKampe and Harald Weber

GMGO, Germany

David J. Ride, Tim Higgs, and Chris Jones

CBDE, Porton Down, UK

Kenneth Nyren and Per-Erik Johansson

FOA, Sweden

Jürgen Streicher

DLR, Germany

## 1 INTRODUCTION

The measurements and results presented here were obtained during the MADONA experiment performed at Porton Down, UK, in 1992. A more detailed description of the experiment is given in Cionco et al. (1995). One of the purposes has been to establish a set of data containing concentration fluctuations to evaluate existing models for short range dispersion, and to improve the understanding of the natural process of concentration fluctuations.

On the basis of the obtained measurements the concentrations have been analyzed in different frames of reference: the normal fixed frame, the conditional frame, and the moving frame. Often the conditional frame, i.e., the removal of zero concentrations in the measured data, is mistaken as the moving frame (i.e., a frame which follows the instantaneous center of a plume). The present paper shows that there is a profound difference between the result obtained in those three different frames.

Finally the approach of the meandering plume model is discussed and compared with the analyzed concentrations.

## 2 INSTRUMENTAL SETUP

In the experiments artificially generated smoke was continuously released 0.5 m above the ground. The smoke consisted of particles of  $\text{SiO}_2$  and  $\text{NH}_4\text{Cl}$  with an average diameter of approximately  $0.5 \mu\text{m}$ . The smoke produced a white visible plume detectable up to several kilometres down wind. The particle concentrations were measured by a Mini backscatter lidar system, Jørgensen and Mikkelsen (1993). Under quasi-stationary conditions and a steady release of smoke the measured backscatter by the mini-lidar can be assumed to equal concen-

trations with an unknown conversion factor. From other experiments simultaneous measurements of  $\text{SF}_6$  tracer in sample backs and smoke particles measured with the lidar have shown that the conversion from backscatter to concentration is very robust. The conversion factor between the measured backscatter and concentrations varied, however, from one experiment to another, Scholten et al. 1994.

The lidar measurements made during the MADONA experiment are relative measures of the concentrations, but for the study of plume dispersion and fluctuations around the mean concentration the measurements have so far not been preceded with respect to a combined high detailed spatial and temporal resolution, Jørgensen and Mikkelsen (1993).

The cross-wind concentration profiles of the artificial generated plume were measured at  $1/3 \text{ Hz}$  with a spatial resolution of 1.5 m, corresponding to the effective instrument response, but digitized with 0.6 m. During the campaign the Lidar was measuring at different down wind positions ranging from 100-700 m from the source. Figure 1 shows the experimental setup for the lidar measuring the artificial plume.

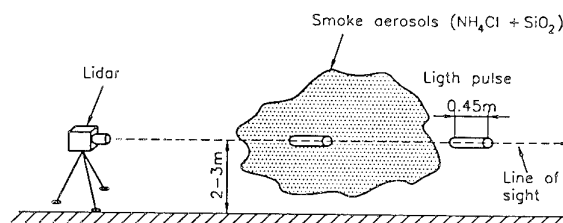


Figure 1: Schematic setup of the lidar system measuring an aerosol cloud.

An example of an instantaneous cross-wind concentration profile measured by the lidar system is

\* Corresponding author address: Hans E. Jørgensen, Department of Meteorology and Wind Energy, Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark.

shown in figure 2. It is seen that the lidar is able to reveal a high amount of the internal structure that occurs in an instantaneous plume.

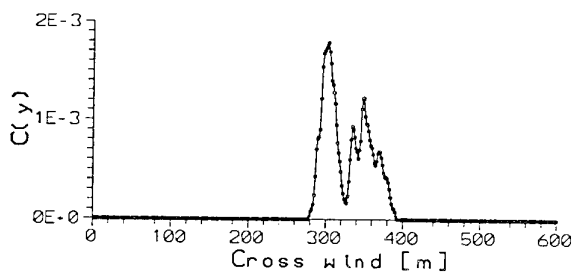


Figure 2: An instantaneous cross-wind concentration profile measured with the Risø's mini-lidar system. The spatial resolution is approximately 1.5 m.

### 3 CONCENTRATION FLUCTUATIONS IN DIFFERENT FRAMES OF REFERENCE

In the analysis of the concentration fluctuations three different frames of reference have been used, two of which other researchers have used most commonly, Sawford (1986), i.e., the conditional and the fixed frame. The third frame is called the moving frame. The definitions of the three frames are:

- **Fixed frame** The coordinate system is based on an Eulerian Cartesian grid fixed relatively to the ground.
- **Moving frame** The coordinate system is based on a moving plume-relative Cartesian grid.
- **Conditional frame** As the fixed frame, but with all the observed zero's, i.e., values under a specified threshold is removed.

In this paper only one of several experiments is presented; the experiment analyzed mad18a was conducted 18 Sept, 1992 at 17:42-18:42. The meteorological conditions were near neutral conditions with SE winds of 4 to 1 m/s. The lidar was located 550 m down wind of the source and position 250 m perpendicular from the plume centre line, Higgs and Ride (1994). Within the three different defined frames the fluctuation intensity  $i(y)$  has been calculated, defined as:

$$i(y) = \frac{\sqrt{c'^2(y)}}{c(y)} \quad (1)$$

The different results of the fluctuation intensity  $i(y)$  is shown in figure. 3

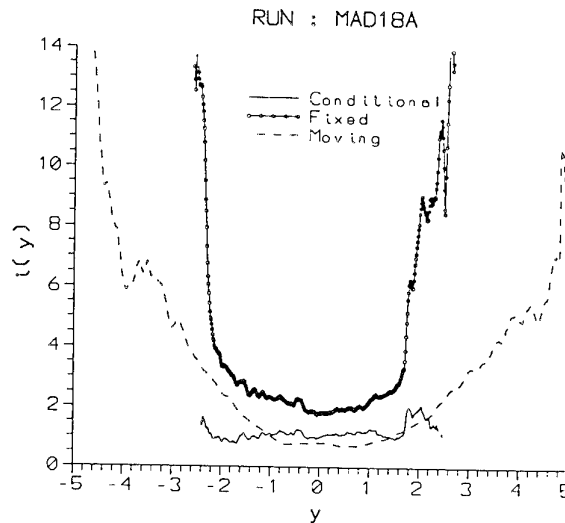


Figure 3: The fluctuation intensity in the three different frames. The x-axis is normalized by the plume size  $\sigma$

The fluctuation intensity in the fixed frame has the anticipated U-shape also observed by several other researchers. In contrast to the fixed frame the conditional intensity is constant across the plume in good correspondence with wind tunnel measurements. Knowing the intermittency, i.e., the fraction of zero concentration, a simple analytic relationship between the two frames exists, Sawford (1988).

In the moving frame the shape of the intensity is closer to the fixed frame shape, but with a significantly lower level of the intensity in the centre line of the plume. The differences observed within those two frames are caused by the meandering of the plume. The difference between the moving frame and the conditional frame is obvious both in shape and in the level of the intensity. The conditional frame does not account for the relative position of the sensor point to the centre line in the instantaneous plume, but accounts for the variances as long as plume material is present. The moving frame, however, accounts both for the meandering and the relative position of the sensor to centre line in the instantaneous plume.

The cross over point where the intensity in the conditional frame becomes lower than the moving frame is approximately 1.5 plume widths. Here the intermittency in the moving frame drops from 100 % to zero at 1.5 plume widths, see figure. 4, indicating the entrainment of clean air into the instantaneous plume

The shape of the intermittency profile for the present experiment is not unique but is shown as reproducible in similar measurements of plumes from ground releases, Jørgensen (1994).

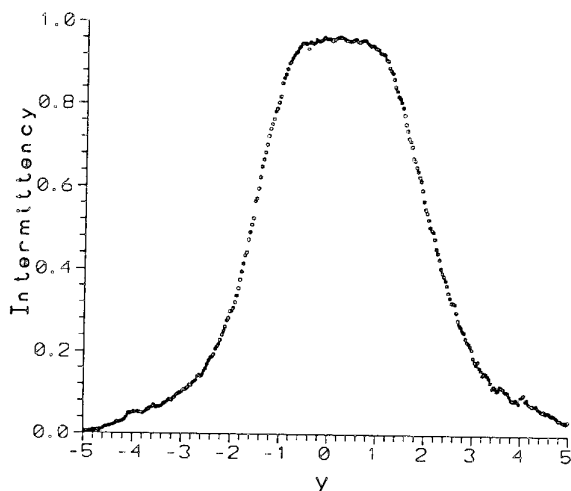


Figure 4: The intermittency of moving frame concentration profile

#### 4 SIMULATION OF $C'$ BY A MEANDERING PLUME

From each of the cross-wind concentration profiles the centre position  $C_L$  of the instantaneous plume has been calculated and plotted, see figure 5

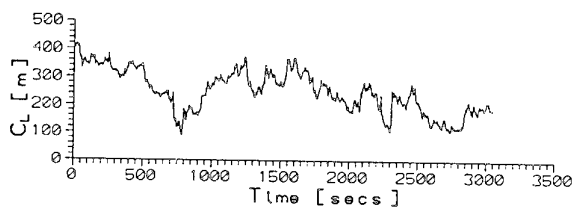


Figure 5: Time series of the  $C_L$  positions

The meandering model often assumes that the distribution of the meandering is Gaussian, which for a quasi-stationary period is a reasonable assumption. The mean profile in the moving frame, which corresponds to the ensemble averaged instantaneous plume, has been observed to be near Gaussian as well, see figure 6.

Assuming that there are no internal fluctuations within the instantaneous plume the concentration fluctuation can be simulated by the use of the following equation, Gifford (1959), Sawford (1983):

$$\langle c^2 \rangle = \int \langle c_m(y - C_L) \rangle^2 P(C_L) dC_L \quad (2)$$

where  $P(C_L)$  is the distribution of the meandering.

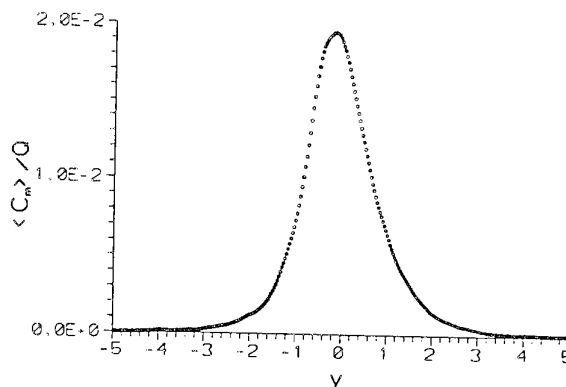


Figure 6: The mean concentration profile  $\langle c_m \rangle$  within the moving frame

The concentration fluctuations are then determined by:

$$\langle c'^2 \rangle = \langle \bar{c}^2 \rangle - \langle c \rangle^2 \quad (3)$$

To illustrate the possibilities of the meandering models the measured time series in the centre line is compared to a simulated time series. The simulated time series is created by moving the ensemble averaged instantaneous plume with the actual time series of the centre line positions. Both the simulated and measured time series are shown in figure 7.

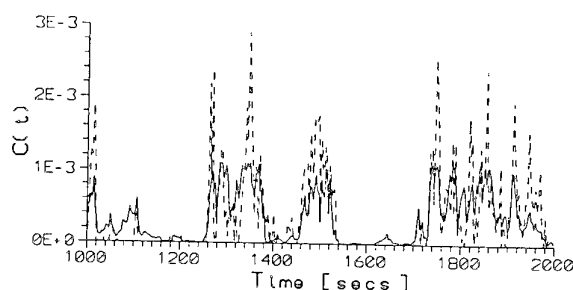


Figure 7: Time series of the concentration in the mean centre line  $y = \langle C_L \rangle$  simulated (full line) and observed (stipled).

The results show that in coarse detail the measured time series can be reconstructed, but the high frequency part of the concentrations is missing. Yee et al. (1994) have incorporated this part by applying a model of the pdf for the internal fluctuation in the moving frame. The model assumes that the behavior of the fluctuation intensity in the moving frame is similar to the one in the conditional frame. The intensity is here assumed to be constant across

the ensemble averaged instantaneous plume. The pdf of the fluctuations is taken to be a gamma distribution, which has shown to fit conditional statistics well, Deardorff et al (1988). The model behaves well, although the basic assumptions do not correspond with the physical behavior of the moving frame statistics measured in the MADONA experiments, see figure 8 (In Yee's model the measured moving frame intensity is here used instead of the conditional frame intensity).

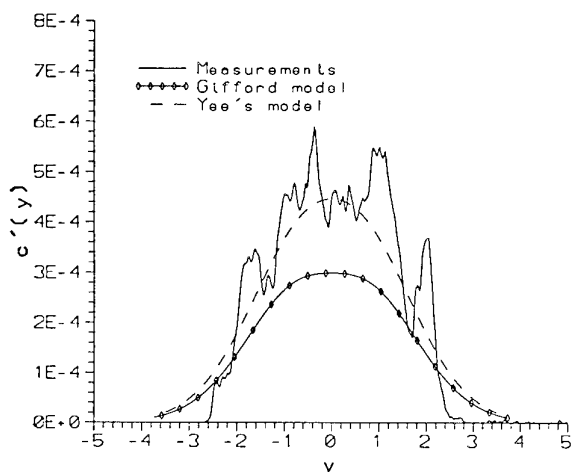


Figure 8: Cross wind profile of the fluctuations  $c'$  compared with the meandering model without internal fluctuations, and the model of Yee with internal fluctuations.

However, a more physically based model should contain the correct form of the fluctuation intensity in the moving frame. Finally it still remains to determine the behavior of the centre line intensity in the moving frame as a function of travel time etc.

## 5 CONCLUSIONS

The experiments contained in the MADONA data base contribute important information on statistics in the moving frame for incorporation into models that are based on meandering of plumes. The analyzed experiment shows a big difference in the statistics in the different frames. This difference is important for understanding the phenomena that create fluctuations in dispersion plumes. For short range dispersion models a large amount of the variance is accounted for by the on-off process caused by the meandering of the plume.

## ACKNOWLEDGMENTS

Part of this work has been sponsored by the Danish Environmental Strategic Research program.

## REFERENCES

- Cionco R.M., W. aufm Kampe, C.Biltoft, J.H.Byers, C.G.Collins, T.J.Higgs, A.R.T. Hin, P.-E. Johansson, C.D. Jones, H.E. Jørgensen, J.F. Kimber, T. Mikkelsen, K. Nyren, D.J. Ride, R. Robson, J.M. Santabarbara, J. Streicher, S Thykier-Nielsen, H. van Raden, H. Weber (1995). An overview of MADONA: A multi-national field study of high-resolution meteorology and diffusion over complex. Submitted to: *Bulletin of the American meteorological Society*
- Deardorff, J.W and Willis, G. E. (1988). Concentration fluctuations within a Laboratory convective boundary layer. In : A. Venkatram and J. C. Wyngaard (eds). *Lectures on Air Pollution Modeling*. AMS, Boston, MA, pp 357-384.
- Jørgensen, H.E. and T. Mikkelsen (1993). Lidar measurements of plume statistics. *Boundary-Layer-Meteorol.* **62** pp.361-378.
- Jørgensen, H.E. (1994). Studies of concentration fluctuations in the atmospheric surface layer. *RISØ-729(EN)*.
- Gifford, F.A. (1959). Statistical properties of a fluctuating plume dispersion model. *Adv Geophys.* **6** pp. 117-137.
- Sawford, B. L. (1983). The effect of Gaussian particle pair distribution functions in the statistical theory of concentration fluctuations in homogeneous turbulence. *Quart. J. R. Met. Soc.*, **109**, pp. 339-357.
- Sawford, B. L. and Stapountzis (1986). Concentration fluctuations according to fluctuating plume models in one and two dimensions. *Boundary-Layer-Meteorol.*, **37**, pp. 89-105.
- Sawford, B. L. (1986). Conditional concentration statistics for surface plumes in the Atmospheric boundary layer. *Boundary-Layer-Meteorol.*, **38**, pp. 209-223.
- Scholten, J.J. Erbrink, A. van Melle, H.E. Jørgensen, T.Mikkelsen, E. Lyck, P.Løfstrøm and T. Ellermann (1994). Atmospheric dispersion at a nuclear power plant building: - A tracer experiment and model evaluation. 40357-KES/MLU 93-3226, available at the Library of KEMA, the Netherlands.
- Higgs, T.J and D.J. Ride (1994). Trial Madona - A field experiment to measure high resolution wind fields and concentration fluctuation over complex terrain. CBDE field trial report no. 127.
- Yee, E., R. Chan, P. R. Kosteniuk, G.M. Chandler, C.A. Biltoft and J.F. Bowers (1994). Incorporation of internal fluctuations in a meandering plume model of concentration fluctuations. *Boundary-Layer-Meteorol.*, **67**, pp. 11-39.

**Bibliographic Data Sheet****Risø-R-852(EN)**

---

**Title and authors(s)**

Final Data and Analysis Report on: High-Resolution in Plume Concentration Fluctuations Measurements using Lidar Remote Sensing Technique

Torben Mikkelsen, Hans E. Jørgensen, Søren Thykier-Nielsen, Søren W. Lund and Josep M. Santabarbara

---

ISBN		ISSN	
87-550-2124-7		0106-2840	
Dept. or group		Date	
Meteorology and Wind Energy Department		November 1995	
Pages	Tables	Illustrations	References
102	2	17	7

---

**Abstract (Max. 2000 characters)**

The multi-nation, high-resolution field study of Meteorology and Diffusion over Non-uniform Areas (MADONA) was conducted by scientists from the United States, United Kingdom, Germany, Denmark, Sweden, and The Netherlands at Porton Down, Salisbury, Wiltshire, UK during September and October 1992. The host of the field study was the Chemical and Biological Defence Establishment at Porton Down. MADONA was designed and conducted for high resolution meteorological data collection and diffusion experiments using smoke, sulphurhexafluoride (SF<sub>6</sub>), and propylene gas during unstable, neutral, and stable atmospheric conditions in an effort to obtain terrain-influenced meteorological fields, dispersion, and concentration fluctuation measurements using specialized sensors and tracer generators. Thirty-one days of meteorological data were collected during the period 7 September through 7 October and 27 diffusion experiments were conducted from 14 to 23 September 1992. Puffs and plumes of smoke and SF<sub>6</sub> were released simultaneously for most of the experiments to gauge the resultant diffusion and concentration behavior. Simulations of airflow and diffusion over the MADONA topography were made with a variety of models. Wind fields and wind-related parameters were simulated with several high resolution wind flow models. A tally of the various data gathering activities indicates that the execution of MADONA was highly successful. Preliminary use of the data sets is showing the high quality and dept of the MADONA data base. This well-documented data base is suitable for the evaluation and validation of short range/near field wind and diffusion models/codes. The data base has been placed on CD-ROM media in a structured way by CBDE, Porton Down.

---

**Descriptors INIS/EDB**

AIR POLLUTION MONITORING; COMPUTERIZED SIMULATION;  
COORDINATED RESEARCH PROGRAMS; DATA BASE MANAGEMENT;  
DIFFUSION; EXPERIMENTAL DATA; FLOW MODELS; FLUCTUATIONS;  
M CODES; METEOROLOGY; PLUMES; REMOTE SENSING; TRACER  
TECHNIQUES; TURBULENCE; WIND

---

Available on request from Information Service Department, Risø National Laboratory  
(Afdelingen for Informationsservice, Forskningscenter Risø), P.O. Box 49,  
DK-4000 Roskilde, Denmark  
Telephone (+45) 46 77 46 77, ext. 4004/4005  
Telex 43 116 · Telefax (+45) 46 75 56 27



## Objective

The objective of Risø's research is to provide industry and society with new potential in three main areas:

- *Energy technology and energy planning*
- *Environmental aspects of energy, industrial and plant production*
- *Materials and measuring techniques for industry*

As a special obligation Risø maintains and extends the knowledge required to advise the authorities on nuclear matters.

## Research Profile

Risø's research is long-term and knowledge-oriented and directed toward areas where there are recognised needs for new solutions in Danish society. The programme areas are:

- *Combustion and gasification*
- *Wind energy*
- *Energy technologies for the future*
- *Energy planning*
- *Environmental aspects of energy and industrial production*
- *Environmental aspects of plant production*
- *Nuclear safety and radiation protection*
- *Materials with new physical and chemical properties*
- *Structural materials*
- *Optical measurement techniques and information processing*

## Transfer of Knowledge

The results of Risø's research are transferred to industry and authorities through:

- *Research co-operation*
- *Co-operation in R&D consortia*
- *R&D clubs and exchange of researchers*
- *Centre for Advanced Technology*
- *Patenting and licencing activities*

To the scientific world through:

- *Publication activities*
- *Co-operation in national and international networks*
- *PhD- and Post Doc. education*

Risø-R-852(EN)  
ISBN 87-550-2124-7  
ISSN 0106-2840

Available on request from:  
Information Service Department  
Risø National Laboratory  
P.O. Box 49, DK-4000 Roskilde, Denmark  
Phone +45 46 77 46 77, ext. 4004/4005  
Telex 43116, Fax +45 46 75 56 27  
<http://www.risoe.dk>  
e-mail: [risoe@risoe.dk](mailto:risoe@risoe.dk)

## Key Figures

Risø has a staff of just over 900, of which more than 300 are scientists and 80 are PhD and Post Doc. students. Risø's 1995 budget totals DKK 476m, of which 45% come from research programmes and commercial contracts, while the remainder is covered by government appropriations.